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The Plant Resources of Peru

Cotton, sugarcane, rice, maize, yuca, bananas, flax and olives grow on the coastal lowlands; oca, ullucu, añu, quinua and temperate climate fruit trees in the mountains; cinchona, coffee, mahogany, Spanish cedar, palms, bamboo and cubé in the forested montaña.

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Introduction

PERU's economy, like that of most South American countries, is based upon agriculture. From pre-Incaic days to the present time crop plants have been the most important of her natural resources, and this in spite of the fact that the greater part of her habitable terrain is either inhospitable desert, uncultivable mountain slopes or impenetrable lowland rain-forest. In the face of such difficulties ancient Andean civilizations, culminating in the Incas (1200–1500 A.D.), raised agriculture and agricultural practices to the highest degree encountered in the Western Hemisphere at the time of the Spanish Conquest.

The two most important food plants indigenous to the New World—maize (*Zea Mays* L.) and potato (*Solanum tuberosum* L.)—were possibly brought into cultivation for the first time by ancient Peruvians, who, in their heyday, not only had domesticated about 70 native species but also were familiar with the products of more than 200 different plants. Several of these are familiar species, including:

Chili (*Capsicum frutescens* L. var. *longum* (DC.) Bailey): The orange-red fruits yield a pungent condiment, cayenne or red pepper, and are used in other culinary ways; also medicinally.

Cinchona (*Cinchona* spp.): The source of the all-important febrifuge, quinine, and of similar alkaloids.

Cherimoya (*Annona Cherimolia* Mill.): The green spherical or conical fruits up to 10 inches long are an esteemed tropical dessert fruit.

Coca (*Erythroxylon Coca* Lam.): The leaves are used as a masticatory by the natives and are the source of cocaine.

Cotton (*Gossypium peruvianum* Cav.): The seed-borne fibres constitute the world's most important textile material (including other species and varieties of the same genus).

Guava (*Psidium Guajava* L.): The yellow berry-like fruit, two inches long, is eaten raw or used in jellies, preserves and pastes.

Kidney Bean (*Phaseolus vulgaris* L.): The common "garden", "snap" or "string bean".

Lúcumo (*Lucuma obovata* H.B.K.): A name applied to a common edible tropical fruit.

Lima Bean (*Phaseolus lunatus* L.)[2]

Peanut (*Arachis hypogaea* L.)[2]

Pineapple (*Ananas comosus* (L.) Merr. = *A. sativus* Schult. f.)[2]

Tomato (*Lycopersicon esculentum* Mill.)[2]

[1] Formerly Botanist (1943–1945) of the U. S. Government Cinchona Mission, Lima, Peru.

[2] Too well known to need comment here.

Less familiar to us because less widely cultivated outside their native Andes are:

Achira (*Canna edulis* Ker-Gawl.): The tubers are a source of arrowroot.
Añu (*Tropaeolum tuberosum* Ruiz & Pav.): Furnishes an edible tuber.[3]
Arracacha (*Arracacia esculenta* DC.): The tubers are the edible "Peruvian carrot".
Jataco (*Amaranthus caudatus* L.)
Llacou (*Polymnia sonchifolia* Poepp. & Endl.)
Oca (*Oxalis tuberosa* Molina): Furnishes an edible tuber.[3]
Ullucu (*Ullucus tuberosus* Caldas): Furnishes an edible tuber.[3]
Quinua (*Chenopodium Quinoa* Willd.): Furnishes a cereal-like crop.
Ccañihua (*Chenopodium pallidicaule* Aellen): Furnishes a cereal-like crop.

Since the conquest, Peru has continued her gifts of new plants to the world, chiefly to the field of horticulture, including garden favorites in the following genera:

Calceolaria	*Gongora*
Crocopis	*Mirabilis*
Dieffenbachia	*Schinus*
Eustephia	*Stenomesson*
Fittonia	*Tropaeolum*
Fuchsia	*Urceolina*

Outside this edible and floricultural galaxy is an insecticidal plant, cubé (*Lonchocarpus* spp.). Of little importance prior to this decade, this lowland genus has now become one of the most valuable sources of rotenone. Undoubtedly many other potentially useful species of economic plants remain yet to be discovered.

That many Peruvian plants are now grown widely in temperate as well as tropical parts of the world emphasizes the fact that Peru has a wide range of climates, at least as far as temperature is concerned, brought about not only by her great latitudinal length (3° to 18° south latitude) but also by her high elevation (up to 22,000 ft.). Although situated close to the equator in the north, the cool weather of the Andes makes it possible for Peruvians to cultivate both native and introduced temperate species as well as tropical and sub-tropical species which can be grown of course in the lowlands. Sometimes overlooked, by Peruvians especially, is the fact that certain temperate species, originating in high latitudes, require for their maturing special environmental factors, such as long daylight hours, which cannot be duplicated close to the equator. And certain native plants of the Peruvian Andes may refuse to grow in high temperate latitudes because of similar reasons.

Agriculture in Peru, like the country's natural vegetation, is divisible on the basis of the three principal physiographic zones, known locally as the coast (La Costa), the mountains (La Sierra) and the forested country (La Montaña).[4] Each of these agricultural regions has its characteristic crops, but because of the difficulty and expense of transportation across the Andes, large scale agricultural production is still practiced mainly along the Pacific coast.

Plant Resources of the Coast

Coastal Peru is an almost rainless desert region, yet curiously enough on this narrow belt are grown the country's two most important crops, cotton and sugar. About 52 small rivers flow west-

[3] See abstract of article by Dr. Hodge concerning these tubers, on page 136.

[4] Elsewhere in Latin America the Spanish word "montaña" is used to define mountainous areas, but in Peru it is applied to all forested land whether in the mountains or in the lowlands.

ward to the Pacific from their watersheds high in the Andes. About 40 of these streams have sufficient water to form marginal oases of cultivated land, maintained by irrigation. Some of the smaller rivers dry up completely during a part of the year; others are utilized so well that their waters are thoroughly exhausted before reaching the sea. Irrigation, which started under pre-Incaic agriculturists, is still the fundamental technical problem of Peruvian coastal agriculture. The best desert areas suitable to crop growing under efficient irrigation are now in use. Any expansion of total crop production on the coast will depend on expensive new irrigation projects. Since 1920, when the Peruvian Government initiated a regular program of desert reclamation, close to 741,000 acres of new land have been turned over to coastal agriculture through national financing, and at the present time more than a million acres are under cultivation on the coast. Most of this acreage is in cotton or sugarcane, crops whose cultivation are limited principally to that zone of oases which lies between Ica and Piura. The accessibility of the coastal valleys to the sea and to the main paral-

FIG. 1. Map of Peru showing production centers of various crops. Note that tobacco, cotton, kapok, rice, sugarcane, grapes and olives grow in the coastal area; wheat, barley, olives and grapes in the sierra area; tobacco, balata, rubber, coca, cubé, cinchona and coffee in the forested area.

FIG. 2. Map of Peru showing approximate physiographic divisions of the country, *viz.*, coastal (left) up to 4000 feet, sierra (middle) from 4000 to 22,000 feet, and forested (right) from 200 to 10,000 feet.

leling highway has facilitated economical transportation and commerce, and is the major reason why the principal center of Peru's population is on the coast.

Cotton. The main crop plant of the coast and the backbone of Peruvian economy is cotton. It constitutes the principal agricultural export commodity and one of the oldest of the crops, with at least one native species, Peruvian Full Rough (*Gossypium peruvianum*), having been in cultivation since the pre-Columbian period. Cotton has added significance in the country's economy in that the greater part of it is produced on small land holdings. Eighty-five per cent of Peru's total cotton production comes from a high quality, disease-resistant variety called Tangüis, developed in Peru in 1912 from Smooth or Egyptian cotton. Tangüis is the whitest of the world's cotton varieties and always has brought premium prices in the world's cotton markets. The only other important variety today is Pima cotton with a restricted market but bringing a higher price than Tangüis. Of the coastal departments (*i.e.*, the states), Lima produces about 60%, Ica 25%, Piura 15% and the other departments the balance of the total crop. Piura, in northern Peru, is the center of cultivation of the more precocious and faster maturing Pima variety which is thus better fitted to repel insect attacks common in that area. In order to combat the latter, to keep up the fine qualities of the locally cropped varieties and to aid in the development of disease-resistant forms, the Peruvian Government supports the work of cotton specialists at a modern experiment station at La Molina on the outskirts of Lima.

Cotton is treated as a seasonal crop and is planted in the August–September period. During October 800 pounds of guano fertilizer per acre are applied. Harvesting begins in late April, but the pickings are repeated several times from June to August. An acre of land yields upwards of 643 pounds of raw cotton, well above U. S. production, which when ginned equals 240 pounds of clean fiber and 400 pounds of seed. About 5% of the latter is held for re-seeding, while the remainder is processed. In 1942 the number of acres in cotton was 376,766, producing 72,500 metric tons of fiber, of which 11,250 tons were consumed by the 11 local textile mills; 36,571 tons were exported. In the same year Peruvian mills crushed 113,065 tons of cotton seed to yield 19,500 tons of crude cotton seed oil and by-products.

Sugarcane, introduced shortly after the Conquest, is the second most important money crop in Peru. It is cultivated north of Lima, under very favorable coastal conditions of climate and soils, principally in the irrigated oases of the Chicama, Lambayeque and Santa Catalina valleys (in the Departments of Lambayeque and La Libertad), where 80% of all Peruvian cane is grown. Unlike cotton, a small grower's crop, the greater part of the annual crop of sugarcane is produced by about ten large haciendas. The acreage planted to cane has remained static, and approximately 135,000 acres are currently planted. The yields, which in 1941 in the Chicama and Santa Catalina valleys averaged about seven tons per acre, are very high.

Unlike cotton, sugarcane is a year-round crop which produced 480,000 metric tons of sugar in the period 1941–1942. About 66% of this was exported, principally to Chile, England, the United States and Bolivia. Sugar produced on the coast accounts for about 10% of Peru's exports. Because of high yields, low cost of production and her favorable geographical position in regard to potential markets, Peru's sugar producers are unusually well fitted to endure unfavorable periods in the world's sugar markets. In addition, sugarcane production

has favorable social and economic aspects because the crop can be grown throughout the year, year in and year out, without rotation and on the same land. Employment is thus steady the year round; large sugar estates have grown up, and these offer their workers as favorable a standard of living as exists among any other type of worker in the country.

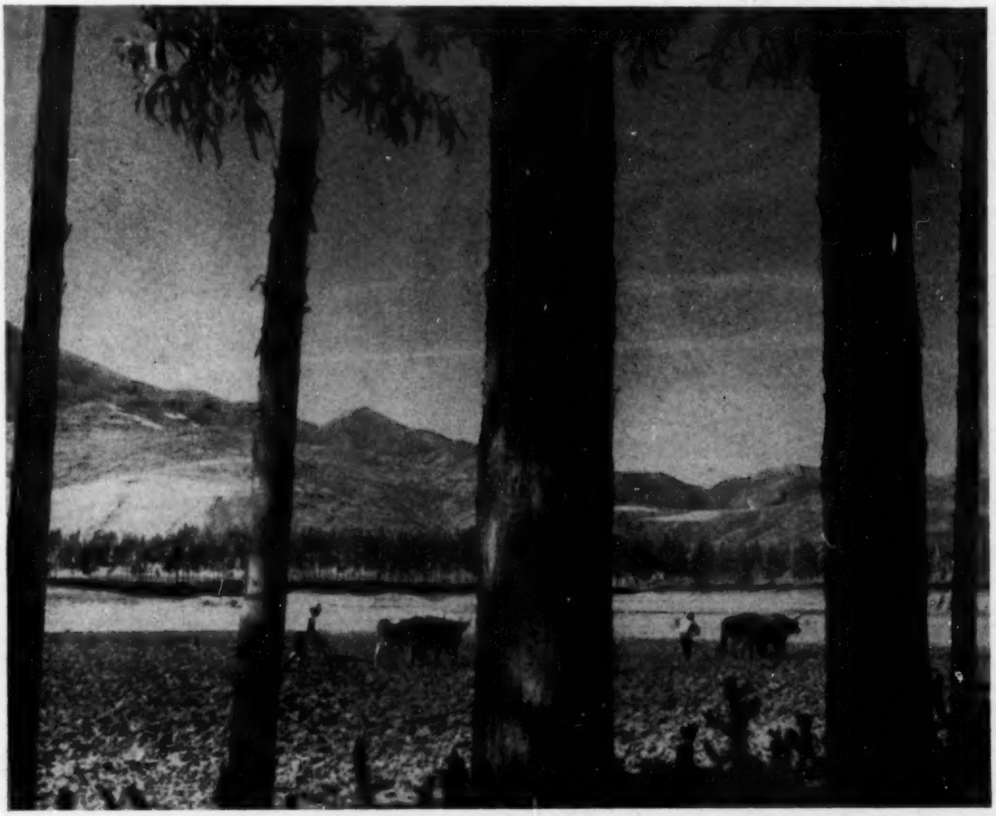


FIG. 3. Ploughing with primitive equipment near Sicuani in the southern Peruvian highlands. These farmers are descendants of the old Incan people. The introduced eucalyptus trees (*Eucalyptus globulus*), bordering the fields, are used for timber and fuel.

The Peruvian sugar industry has not neglected research and experimentation, with the result that sugar production in less than 20 years has been increased 50% without any increase in the total area cultivated. Utilization of the residues from manufacture also goes on. Bagasse is used principally as boiler fuel, although the Grace mill at Paramonga has installed a modern paper factory which makes cardboard containers, wallboard, packing materials and similar products from it which find a ready internal market. Filterpress refuse is used as fertilizer which is run onto the fields *via* the irrigation ditches; molasses, mixed with selected bagasse, goes to make an excellent cattle feed.

Rice, basic food of coastal Peru, is grown in both small and large holdings (totaling approximately 120,000 acres) on the coast, particularly in the sugar-producing departments of Lambayeque, La Libertad and Piura. These departments together produce about 80% of

FIG. 4. (*Upper*). Winnowing wheat in the Vilcanota Valley, south of Cuzco. The white patches on the slopes at the left indicate wheat fields. FIG. 5. (*Lower*). Corn drying in an Indian dooryard in the Sandia Valley of southern Peru.

the annual crop, which in recent years has averaged between 75,000 and 100,000 tons, a total insufficient to supply the internal consumption.

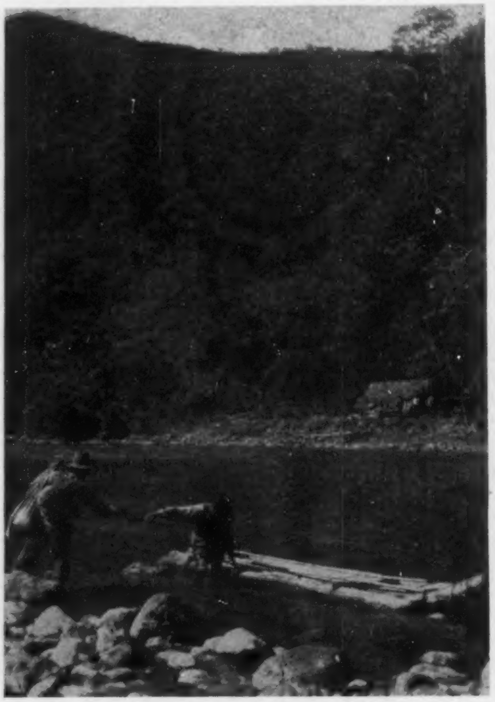
Kapok. Kapok-yielding ceibos (*Bombax* spp.) are common and dominant members of the xerophytic forests, located on the westernmost slopes of the Andes in the northern Department of Piura. Ceibos may be seen in relatively large numbers along both the Sultana-Ayavaca road and the Lambayeque-Huancabamba road. They cover a belt approximately 20 miles wide in the foothills, and grow up to approximately 5,000-foot elevations. In this department the writer roughly estimates that there exist a million acres of ceibos with an average of about ten trees per acre, and with a potential kapok-producing capacity of 10,000 tons per crop year. Peruvian kapok is an uninvestigated potential export product, yet the location of these forests—close to the coastal cities of Sullana and Piura—is especially favorable for solving labor and transportation problems. Cotton-ginning machinery, common in this department, could probably be utilized in harvesting the floss which is usually mature in September.

Other crops. A number of miscellaneous agricultural products also are cultivated in the irrigated valleys of the coast. Flax is planted to a small extent in the valleys of Pativilca and Cañete, but increase in plantings of this relatively new crop must await the solving of serious cultural problems. Olives are important in the Valleys of Moquegua (1000 tons a year), Camaná, Victor, Ilo and Azapa. Castor beans are cultivated in the Department of Piura. The Department of Ica is known for its vineyards which annually produce ten million liters of white and red wines as well as three million liters of piscos, or pure grape spirits. Truck gardens are important in the valleys close to Lima, and all along the coast where irrigation occurs may be found sizable plantings of maize, yuca (*Manihot esculenta* Crantz., the source of farinha and tapioca), bananas and plantains, as well as figs, oranges, mangoes and pineapples.

Plant Resources of the Mountains

The Peruvian sierra, or mountain country, embraces an extensive belt, essentially the Andean mass, including lofty, cold deserts and semi-deserts, grasslands and warmer intermont valleys. The sierra is essentially a high treeless region with a cool climate and a seasonal rainfall, and will support most economic plants requiring such a combination of climatic factors. Planting of a few tuber crops, such as hardy ullucus and certain varieties of potatoes, is possible up to the upper limits of cultivation, about 14,000 ft., beyond which the agriculture of the puna is limited to grazing. The zone of grains lies between 10,000 and 13,000 ft., with maize culture extending up to 11,000 ft., wheat up to 12,000 ft. and barley up to 13,000 ft. Sugarcane is grown at altitudes reaching 8,000 ft., while bananas and oranges occur up to 6,000 ft. Irrigation is utilized with most crops, as on the valley oases of the coast, in order to insure a constant and even supply of water; and because of this use, most sierra agriculture is limited to the larger intermont valleys dissecting the Andean plateau. In the Peruvian highlands rains fall generally from October to April which is the growing season for both irrigated and non-irrigated crops.

Unlike the coastal centers of agriculture which have many large estates, the highlands possess small holdings, owned and worked in many districts by the native Indians of the Aymara and Quechua races which form the great bulk of the sierra population. These peoples are still cultivating their native staple crops of maize, potatoes, ocas, ullucus,



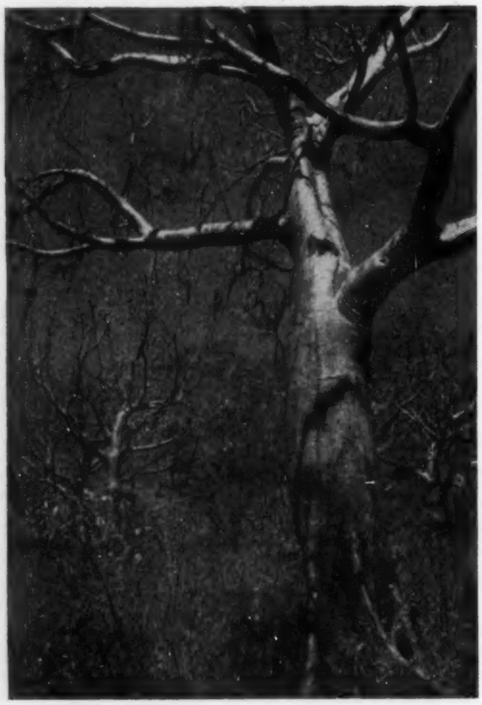


FIG. 6. (*Upper left*). Pruning the old base of a young budded rubber tree at Tingo María, Peru. FIG. 7. (*Upper right*). Seedling rubber trees to be used as budding stock at the joint Peru–U.S.A. Agricultural Experiment Station at Tingo María, Peru. FIG. 8. (*Lower left*). A cinchona bark hunter's camp on the upper Rio Tambopata in the "Ceja de la montaña" of Peru near the Bolivian frontier. High grade quinine bark, *e.g.*, *C. Calisaya*, grows on the ridge at the upper left, and the bark, after removal from the trees, is dried and packed at the camp. FIG. 9. (*Lower right*). Ceibos (*Bombax* sp.) growing in the xerophytic open woodlands of the Chipillico River valley in the Department of Piura. These trees are a source of kapok.

añu, quinua—often on the amazing series of Incan terraces which have persisted to this day in many steep-walled Andean valleys. Although considered the native home of the potato, the highlands of Peru produce a supply barely sufficient to support her coastal and sierra population. Potatoes are, nevertheless, grown throughout the highlands and with the other tuber plants and corn are one of the commonest commodities met with in the primitive Andean markets.

A few varieties of potato and maize have long since been carried around the world, yet it is not generally known that innumerable other obscure varieties with valuable breeding possibilities, still are cultivated only in the high Andes. And it is also surprising that the other flavorsome Andean tubers, in particular the oca and hardy ullucu, have not warranted extensive trial plantings in temperate potato-producing regions of the world. Like the potato with which they are always grown in the Andes they might be developed into new and valuable sources of food.[3] Quinua has had a disappointing introduction to Europe, but even this crop could stand additional study. The importance of quinua as a food among the Indians of the sierra has been recognized by the Peruvian Government which voted a subsidy in 1937 to increase the production and use of this native cereal.

The group of indigenous food plants has been augmented since the Conquest by the introduction of the important Old World grains, wheat and barley, and the forage crop, alfalfa. Wheat formerly was planted on the coast, but today 90% of the country's production is grown—generally without irrigation—on elevated slopes or valleys of the Andes in regions where the more fertile irrigated areas are reserved for corn or potato cultivation. Due to its isolated area of culture, the crop is difficult to transport to the coast, where demand for it is greatest. The present annual wheat production (101,771 tons in 1940) barely accounts for a third of the current Peruvian consumption. The Departments of Junín and Huancavelica are the big wheat producers, while the Huancayo basin is the principal wheat center, accounting for about 40% of the crop. Barley is cultivated to a less extent than wheat and chiefly on the higher and colder altiplano surrounding Lake Titicaca in the southern Peruvian Department of Puno, where it has become an important crop among the highland Indians.

In the intermontane and upper montaña river valleys of the Marañon, Mantaro, Apurimac, Urubamba, Paucartambo and their principal tributaries there is a mild climate suitable to the production of sugarcane. Because of transport difficulties and smaller yield, cane producers of the sierra are unable to compete with coast producers in the production of sugar, and so convert practically all their cane into alcohol, aguardiente, or other industrial spirits. It is estimated that 3% of the sugarcane grown in Peru is crushed in the sierra, but the same region produces 25% of the total alcohol manufactured.

Most of these valley areas also produce temperate and sub-tropical fruits including apples, peaches, plums, quinces, pears, oranges, tangerines, sweet lemons and lemons; wild chirimoyas are also common. Grown to some extent are minor crops such as aniseseed (*Pimpinella Anisum* L.) and pyrethrum (*Chrysanthemum* sp.).

Certain native species of semi-xerophytic middle elevations have been neglected and might be developed into important crop plants suited especially for planting on terrain otherwise unfitted for any other type of agriculture. Examples are tara (*Caesalpinea tinctoria* Domb.) and agave (*Fourcroya* sp.), two plants which are especially abundant in

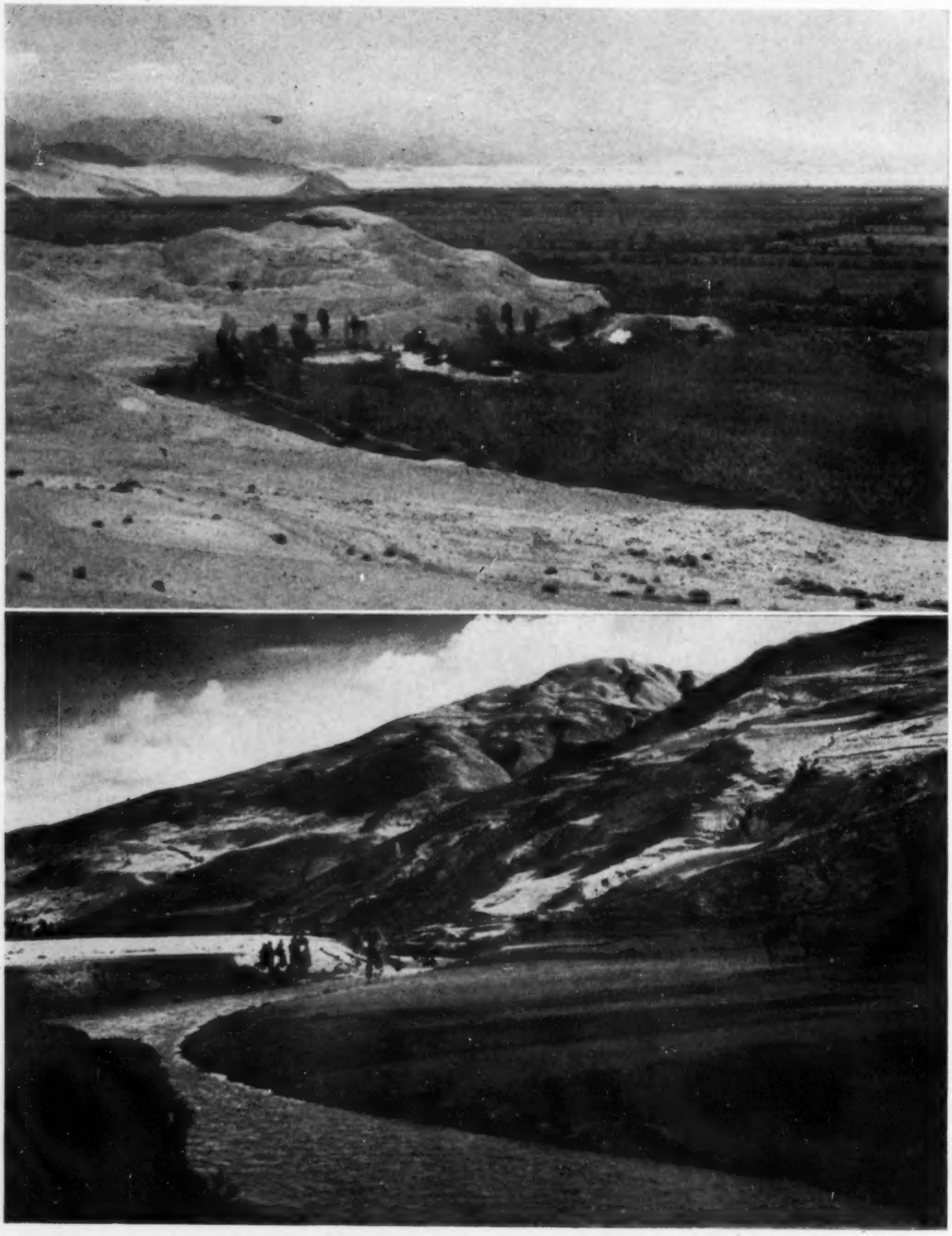


FIG. 10. (*Upper*). Irrigated cotton fields in the typical coastal oasis of Lurín, just out of Lima. This oasis was under cultivation by the ancient Peruvians who had a center, nearby Pachacamac, from which locality this view was taken. The trees are mostly *Salix Humboldtiana.* FIG. 11. (*Lower*). Agricultural use of land in the Vilcanota River Valley, south of Cuzco. On the slopes are wheat fields; on the valley floor, fields of quinua (*Chenopodium Quinoa*) and of an edible lupine (*Lupinus mutabilis*).

the northern half of the Peruvian highlands. The pods of tara, a wild leguminous shrub of the western and intermontane Andean valleys, are very rich in tannin. Moreover, the seeds contain large quantities of pectin which should find some use. Exports of the pod, either whole or powdered, have increased in recent years. In 1943 these exports amounted to nearly 2,200 tons with a value of 490,000 soles ($78,400). Unlike many other tannin plants (*e.g.*, species supplying wood and bark tannins), which are destroyed for their tannin content, tara is uninjured and produces successive crops of pods annually. There is a need for the study of tara culture. Agaves also might lend themselves to cropping in the Andes and could become a more efficient and greater source of fiber which is in universal demand throughout Peru for making baling twine, rope, etc. On the high treeless puna of southern Peru another native plant is of local importance as a combustible. This is the curious cushion-forming yareta (*Azorella yareta* Hauman) whose resinous stems and foliage, when dried, make an intense heat-producing fuel, which is even used to some extent by railroads in the region of the Chilean frontier.

Timber. Perhaps the most serious deficiency of the high sierra country, and the coast as well, is the lack of readily available timber supplies. Most of the habitable highlands lie above the tree-line. The few trees that exist in sheltered areas, like quinuar (*Polylepis* spp.), have been largely eliminated by the highlanders in their unceasing search for firewood. Moreover, the tortuous narrow roads make transportation of lumber by truck up from the nearby montaña forests most difficult. A partial solution to this timber scarcity was the successful introduction of fast-growing Australian species of *Eucalyptus* which are now valuable crop trees throughout most of the highland valleys. The satisfactory growth of eucalyptus at high elevations suggests that other trees, perhaps superior as timber-producers, might also be introduced for forestation purposes.

Plant Resources of the Forested Country (Montaña)[5]

More than 51% of Peruvian territory is forest land, called "montaña", and lies east of the principal Andean axis. The forested area is very moist and is covered for the most part by an evergreen rain-forest formation which extends west from the tropical lowlands of the Amazon basin to the eastern slopes of the Andean front ranges up to timber-line at temperate elevations of about 10,000 to 11,000 ft. In northern Peru where the Andes are lower, bits of temperate montaña forest have crept across the mountains and are to be found as irregular patches on the western slopes in the Departments of Piura, Lambayeque and Cajamarca. These scattered patch forests are actually southern outliers of the forest formation of the western Andean slopes of Ecuador.

Peru's forested areas can be divided into two zones, the ceja de la montaña (literally "eyebrow of the forest"), which includes those fringes of low-statured, temperate, montaña forests bordering upon the cold sierra; and the lowland montaña, composed chiefly of tall tropical rain-forests.

In the mountains, at elevations between 2,000 and 6,000 ft., is the center of cultivation for the three C's of ceja crops—cascarilla, coca and coffee. The first two are native medicinal species; cascarilla (*Cinchona* spp.) is represented by trees whose bark constitutes the source of the important alkaloids quinine, cinchonine, cinchonidine and quini-

[5] For aid in preparing this account of the lowland forest species the writer is indebted to Dr. Russell J. Seibert of the Office of Rubber Plant Investigations, Washington, D. C.

dine; and the shrub, coca, whose leaves are much chewed with lime as a narcotic by the Indians of the sierra, is the source of the alkaloids cocaine and tropacocaine.

Cinchona. The genus *Cinchona* is widespread throughout Peru, but the great majority of the forms are of no commercial importance except as possible budding or breeding stock. Most recently exploited because of critical demand in World War II has been the cinchonine-rich bark of *Cinchona micrantha* Ruiz. & Pav., known in northern and central Peru as "huanuco" and in southern Peru as "monopol". The bark of this species averages between 3% and 4% in total crystallizable alkaloids, mostly cinchonine; and more than 1,144 tons of the bark of this species was harvested during the period 1943–1945. Quinine-yielding species are *C. Humboldtiana* Wedd. (averaging 5%–7% of this alkaloid) of the Department of Cajamarca, *C. rufinervis* Wedd. (averaging 4%–5% quinine) and *C. Calisaya* Wedd. (averaging 4%–7% quinine) of the upper Tambopata and Inambari river valleys in the Department of Puno. These species, though relatively rich in crystallizable quinine alkaloid, are small trees which have been intensively sought and so are relatively few in numbers, and hence unimportant. *C. Calisaya* is the parent species of the high-yielding plantation forms (Ledgeriana strains) cultivated so intensively in Indonesia. *C. Humboldtiana,* a little known species of northern Peru, appears to be even richer than wild calisaya and ought to be introduced into any important cinchona-breeding program. Of more importance to Peru is the current attempt to establish local cinchona plantations with the idea of supplying sufficient quinine-yielding bark for her internal demands. A government plantation, Fundo Sinchono, has already been established east of Tingo María in the Cordillera Azul, and has been stocked with high-yielding Ledgeriana strains. This project was initiated with the financial aid of the United States Government, and as partial repayment for Peru's willing help in exploiting her low-grade, wild, cinchona stands during the war.

Coca. Coca is cultivated as a sierra Indian crop on small chacras (farms) situated in the more-accessible, warm, forested valleys lying on the margins of the montaña in the Departments of Puno, Cuzco, Ayacucho and Huánuco. Most cocales, as coca plantations are called, are to be found between 2,000 and 5,000 ft. elevation; the annual production of coca leaves averages between 5,000 and 6,000 tons, but the greater portion of this total is consumed as a masticatory by the highland Indian population. The 200 to 300 tons of leaves which have been exported annually in recent years have been utilized chiefly in the U.S.A. for flavoring soft drinks. Most pharmaceutical cocaine is obtained from higher-yielding leaves produced in Java.

Coffee. Coffee is cultivated throughout the ceja belt, but in appreciable quantities only in the Chanchamayo Valley of central Peru, and in the north, east of Chiclayo, on the Pacific slopes at Monteseco in the Department of Cajamarca. Peruvian coffee is of a rich grade, and the insignificant production is almost wholly exported. Another Old World beverage plant, tea, has been successfully introduced into the upper forest region of the montaña in recent years. Small areas have been planted in the Huallaga Valley near Tingo María, and already locally-grown tea has made its appearance in the Lima market.

The lowland montaña (Peruvian Amazonia) is the country's chief agricultural frontier and is still a virgin untouched area whose limitations are still its inaccessibility and inadequate population. Great tracts of this country probably will support nothing more valuable than forest. Forest products will be, in fact,

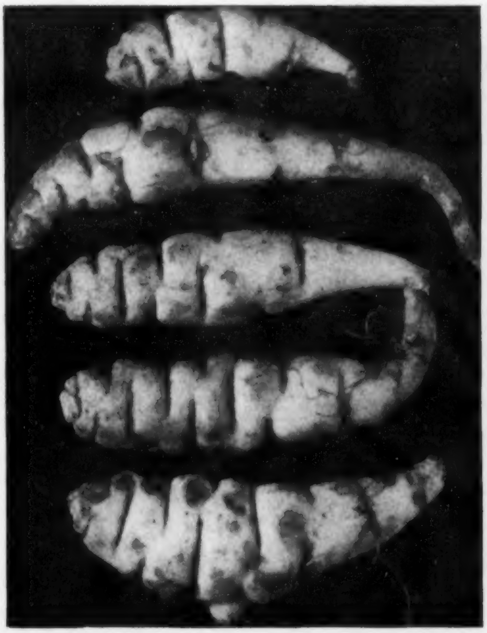
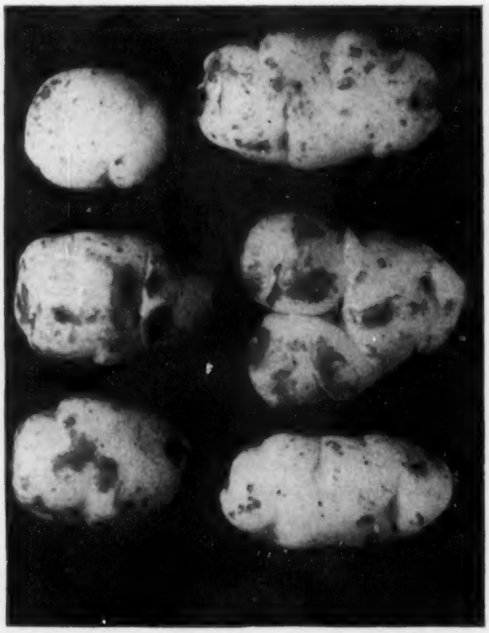



FIG. 12. (*Upper left*). Añu, ***Tropaeolum tuberosum.*** FIG. 13. (*Upper right*). Oca, ***Oxalis tuberosa.*** FIG. 14. (*Lower left*). Ullucu, ***Ullucus tuberosus.*** FIG. 15. (*Lower right*). Potato, ***Solanum tuberosum.*** The large dark ones are fresh; the small light-colored ones are dehydrated and known as ''chuño''; once prepared they keep for years. The broad-brimmed, black-banded hat marks the woman as being from Huancayo.

among the first to be exploited, yet the forests are, except for small areas along the rivers or near long-established settlements, largely unknown. Most of the trees, if identifiable taxonomically, are certainly unknown as far as timber possibilities are concerned. A forest survey is a prime necessity for most all frontier regions in the Peruvian montaña.

Timber. A few better-known tropical hardwoods such as mahogany and cedar are being cut for export; and, as resources of fine cabinet wood diminish in other areas of the hemisphere, the expansion of Peruvian lumbering will certainly follow. Lumber mills exist near Iquitos in the Department of Loreto. Small mills have also been located near the eastern termini of the roads running from Lima to Tingo María, to the Chanchamayo Valley, and to Satipo—all in central Peru. Lumber cut in these areas is brought over the Andes by truck for consumption in Lima. Mahogany (*Swietenia macrophylla* King), locally called "aguano" or "caoba", is the most important export lumber tree in Peru today, and this country is the biggest South American producer of this timber. Mahogany is apparently widespread in the Amazonian area, at elevations of 400 to 3,400 feet, and all the way from northeastern Peru to the southern Madre de Dios region where it is very abundant, though unexploited. Unfortunately the greater proportion of Peruvian mahogany, because of its scattered distribution, is inaccessible; and only trees in the central area of the montaña, in the basin of the Huallaga and Ucayali Rivers, are now cut—the logs being then rafted to the mills at Iquitos. To obviate the difficult and expensive search for widely scattered isolated trees—a distribution characteristic of most tropical rainforest species—the Iquitos mills, believing the greatest future for mahogany in Peru to lie in plantation-grown timber, are resorting to experimental plantations of this species. To date, about 15,000 trees have been planted. If such plantations are successful—and no plantation of a tropical American timber tree has yet succeeded—some sort of permanent managed program may be established. Practically the entire mahogany production of Peru is exported as sawed lumber, and the greater proportion in recent years has gone to the United States; 2,500,000 board feet were exported in 1939, and during World War II the Peruvian lumber was a high-priority product, particularly because it excels the same type of mahogany in other areas in its bending, compression and shearing strength.

Second in importance as a commercial timber species is Spanish cedar (*Cedrela odorata* L.), commonly called "cedro colorado". Cedar is an abundant tree along the banks of rivers and streams, and its geographical distribution and exploitation in Peru coincides with that of mahogany, with which it associates. Thus, although cedar is a large and very abundant tree in the Department of Madre de Dios, its exploitation likewise is limited to the Huallaga and Ucayali valleys. As with mahogany, the timber is floated to Iquitos. The fine wood of cedar is the most widely used construction timber in eastern Peru, and besides is the only native timber shipped in large quantities to western coastal Peru *via* the long Amazon River and sea route. Small quantities of cedar are exported.

It is interesting to note that these two most important commercial hardwoods are species widespread in tropical America. Their exploitation in Peru dates from a comparatively recent time and post-dates their use elsewhere. Not a single tree species of Amazonia is of similar economic importance, yet this is certainly not due to the fact that such native species are absent from lowland Peru but rather can be explained by the fact that the other valuable timbers have yet not only to be discovered but also

need to have their wood properties investigated scientifically. Important fine hardwood species aiding the expansion of the Peruvian lumber industry will undoubtedly be encountered among the Peruvian representatives of the Lauraceae as well as among such locally important timber species as tornillo (*Cedrelinga catenaeformis* Ducke) of the Upper Huallaga; and castaña (*Bertholletia excelsa* H.B.K.), estoraque (*Myroxylon Balsamum* (L.) Harms), huacapu (*Lindackeria maynensis* Poepp. & Endl.), mashonaste (*Anonocarpus amazonicus* Ducke), palo vibora (*Phyllanthus* sp.), quillobordon (*Aspidosperma subincanum* Mart.), and tahuari (*Tabebuia* sp.)—all of the Peruvian Madre de Dios. At least one of these timber species, castaña, is the producer of a potentially-important export item, the Brazil nut, which is also utilized locally to make oil. The species is very abundant—two or three trees per hectare—in the Peruvian Madre de Dios.

Latex. Timber is but one class of products obtained from tree species of lowland Peru. One of the better-known non-timber products is the latex of the Para rubber tree (*Hevea brasiliensis* Muell.), called "jebe fino" and widespread throughout the great Amazon basin. The saga of rubber's introduction to the Far East is too well known to be repeated here. Suffice it to say that World War II stimulated the return and development of a plantation rubber industry in Latin America. Peru's production of wild rubber in recent years has been insignificant, and even with the stimulus of the recent war the greatest annual production was slightly less than 1,000 tons. Yet present domestic requirements are only about 500 tons per year, a quantity which could be produced regularly, especially if the new plantations initiated in the northeastern part of the country are successful. Iquitos and Puerto Maldonaldo are the chief collecting centers for wild rubber. Peru has aided the Hemisphere Plantation Program especially in supplying wild seed from disease-resistant and extremely high-producing strains, not hitherto known to exist in Amazonia. Many of these wild types are from the out-of-the-way Madre de Dios section where they were discovered by the botanists of the U. S. Department of Agriculture. Careful selection and breeding of these new strains at the several experimental rubber plantation centers of Latin America should produce stock which can be grown even in Peru with its ravaging South-American leaf blight. Disease-resistant rubber can be then a new permanent and readily-available "cash crop" for the small farmer of the eastern lowlands.

Goma debil (*Hevea lutea* Muell.) and caucho (*Castilla Ulei* Warb.) are two other widely distributed latex trees producing poor-grade rubbers. Next to the Para rubber tree, the most important Peruvian latex-yielding species is *Manilkara bidentata* A. DC., scattered wild trees of which supply on an average annually several hundred tons of balata, a non-elastic substance used in the manufacture of insulation. The principal balata-producing areas of the montaña are the basins of the Putumayo, Marañon, Napo, Ucayali, Nanay and Huallaga Rivers. The coagulated latex, gathered from felled trees, is shipped to Iquitos for export. Miscellaneous other latices—obtained principally from *Parahancornia amapa* Ducke and species of *Sapium*, *Pseudolmedia* and *Lucuma*—, are sometimes used as balata adulterants.

Palms. Potentially one of the most important groups of plants of the Peruvian montaña, and one of which very little is known, is that of the palms with a widespread distribution throughout Amazonia. Only a single species, *Phytelephas macrocarpa* Ruiz. & Pav., the tagua palm, is of much economic importance, its hard white seed supplying the

"vegetable ivory" of commerce, which recently has been exported from Iquitos in amounts averaging about 1,000 tons annually. Although only the tagua palm finds more than local use there yet exist dozens of potentially more important palms whose products are at present used only by lowland forest Indians. The chambira palm (*Astrocaryum* spp.), besides producing one of the strongest epidermal leaf fibers—locally made into cord for fish lines, hammocks, *etc.*—also has seed kernels rich in palm oil. The fine pulp oil of various species of the genus *Jessenia* also has commercial possibilities; and chonta or pijuayo (*Guilielma gasipaes*) has a tough, close-grained, flexible wood which could be utilized in the manufacture of high-grade sporting articles such as fish-poles, gun-stocks, *etc.* A distinguished authority on palms has recently remarked that the United States has been importing palm oils from halfway around the globe, even though a larger concentration of oil-yielding palms exist in Latin America, with a center in Amazonia, than anywhere else. Peru has her share of these potential but little-known oil producers and should take advantage of their presence, for not only are most palms easily grown in plantations but also many of them—unlike the other species of the tropical rain-forest—form extensive and natural pure stands which lend themselves admirably to exploitation.

Bamboo. The bamboos are another forgotten group which some day may find commercial importance in the lowlands. Marona (*Guadua* sp.) of the Madre de Dios region is a common bamboo whose large culms are very durable and apparently resistant to termites. Foreign bamboos may also prove valuable, and the group needs study from the standpoint of a possible source of wood pulp, a sorely needed item throughout Latin America.

Cubé. The most important recent gift of the Peruvian montaña to the world is the leguminous shrub cubé or barbasco (*Lonchocarpus Nicou* DC.) whose rotenone-bearing roots, long-used by Indians as the source of a fish poison, have been found also to have very effective insecticidal properties. Up to the last decade most commercial cubé root was collected by Indians from their semi-wild forest plantings, but during recent years many small and very successful commercial plantations have been started in the lowlands, particularly in the Iquitos and upper Huallaga regions. These cubé plantings, totalling approximately 7,000 acres and yielding at present about 1,400 tons of crude or powdered roots annually, are not only the primary source of the world's supply but are also the most important export from Peruvian Amazonia. The recent "discovery" and rise of cubé from a mere fish poison of forest Indians to one of the foremost natural insecticides makes one wonder how many other plants, known and used in various ways by lowland Indians, might have economic possibilities in the world's economy. Ethnobotanical studies in Peru are certainly as important as any forest survey and may prove once and for all whether such Indian drug plants as, for example, ayahuasca (*Banisteria* spp.), chuchuhuasha (*Heisteria pallida* Engl.) and oje (*Ficus glabrata* H.B.K.), have any actual value in medicine. Undoubtedly many an important aboriginal plant is still unknown to the world at large.

Other forest crops. Other crops are locally important in various parts of the montaña, but in most cases agricultural practices are primitive, consisting of temporary cultivations where the forest has been felled. Logs and stumps are usually left in place in such clearings so erosion is limited. After a few years of chacra farming the plot is abandoned for a new one. The most important field crops on these small lowland clearings

are maize, beans, rice, sweet potatoes, yuca, and plantains. . . . the two last-named being the staple foods of the region. In the few localities where transportation difficulties are lessened, agriculture is more advanced. This is especially true of such valleys as the Chanchamayo which has trans-Andean highway connections with Lima, and which, as Lima's "fruit basket", supplies the capitol with oranges, bananas, avocadoes, papayas, etc. Small plantations of sugarcane are widely dispersed in the montaña; cacao is produced in the Departments of Loreto, Amazonas and Cuzco; tobacco, a state monopoly, is grown in Tumbes, San Martín and Loreto.

Development of Resources

For years the network of lowland rivers has served as the only means of transportation into the montaña. Products originating in the area and destined for coastal Peru have had to be placed aboard ocean freighters at Iquitos. From that river port they have had to move down the Amazon, through the Panama Canal and then south to Peruvian ports. Transportation costs have thus made prohibitive the development of agricultural resources in the montaña on any large scale.

Peru is taking the initial steps to develop the montaña. Her difficulty hinges not only on deficient transportation but also on the lack of population in her eastern departments. Her problem is shown by the fact that the montaña comprises considerably more than 50% of Peru's total area, yet the population density in the same region is scarcely one person per square mile. For this reason, and rightly, Peru is pushing projects for colonization along several of those trans-Andean roads which have already penetrated into the lowlands. Among these are the highways into the valleys of the Marcapata, the Satipo, the Chanchamayo, and into the upper Huallaga and Ucayali valleys near Tingo María and Pucalpa. In these valleys colonization centers and agricultural stations have been set up and are working hand-in-hand in order to guide new settlers in all phases of tropical agriculture. One of the most important of these Peruvian stations, located at Tingo María, has been established in coöperation with the Department of Agriculture of the United States Government, which has supplied resident specialists in the various fields of agriculture. The most important projects under investigation at present deal with rubber, tea, cinchona, cubé and tropical food plants. Peruvian personnel for this and other agricultural experiment stations, located not only in the montaña but also throughout the whole country, are trained at La Molina, the Government Agricultural School in Lima.

As yet no forest or soil conservation has been initiated in Peru. In a country whose timber resources are vast and unknown this is a serious deficiency. One of the first important tasks should be a forest survey, but forest legislation and organization should also be promoted.

Another need of Peruvian agriculture is greater diversification of crops to enable the country to be self-supporting, at least as regards food plants. With more than sufficient acreage for growing essential crops, Peru yet has to import such basic commodities as rice and wheat, and potato shortages are often frequent in various sections of the country. With better cultural practices and the introduction of modern farm equipment, particularly in the sierra, Peru could make long strides in this direction. The sierra Indians especially, whose ties have long been with the soil, should be schooled in modern agricultural practices. They constitute the sierra population; and unless they are educated, any agricultural program in the important highland region will be a failure.

A forward step in Peruvian agriculture was taken in 1943 with the formation of the Inter-American Coöperative Food Production Service, known as SCIPA, made up of a group of Peruvian and North American agricultural specialists. Prominent on the agenda of this organization are such projects as the increase and improvement of the production of food products; development of plans for crop adjustment; development of new acreage with agricultural colonization; soil conservation; further development of extension work; provision of loans and other means of assistance to small farmers and growers; studies and dissemination of information regarding benefits of diets; and plans for the improvement of transportation, storage and distribution of agricultural products.

Utilization Abstracts

Edible Andean Tubers. In the Andean highland valleys of Venezuela, Colombia, Ecuador, Peru and Bolivia, at elevations of 9,000 to 14,000 feet, there are four important cultivated edible tuber plants. One of them, the potato (*Solanum tuberosum*), is widely known and world-wide in cultivation. The other three have not been accorded the same publicity as has the potato, nor have they been subjected to the same breeding care, and they are therefore only of local importance to the natives in the regions where they are grown. For many centuries they have served as native sources of food, but their cultivation today is being gradually abandoned.

One of these tubers is oca or occa, known around Bogota as "híbia" and in part of the Venezuelan highland as "cuiba". It is the underground portion of *Oxalis tuberosa,* and in some areas is nearly as important as the potato, being the principal crop grown on the terraces of precipitous mountainsides. The upright, branching, succulent herbs, two to three feet tall, do not appear to set seed, as is true of many plants long in cultivation, and propagation is accomplished by cutting up and planting the two-to-three-inch tubers. Several named varieties, distinguished by the color of the tubers and by their degree of sweetness, are recognized by the Peruvian Indians. Oca is planted in primitive fashion at the beginning of the rainy season, and similarly primitive harvesting occurs in April and May. Since the starchy tubers, especially in the bitter varieties, contain crystals of calcium oxalate, they must be mellowed before being eaten, and this is accomplished by placing them in the sunshine for several days. They are then prepared for eating, raw or cooked, in a variety of ways. For storage purposes the tubers are converted into a desiccated form known as "chuño", as is also done with the other tuber crops. This conversion involves prolonged submergence in dammed flowing brooks and subsequent drying and freezing.

Next to ocas in importance are the tubers of *Ullucus tuberosus,* known locally in various regions of its cultivation as "melloco", "ulluco", "olluco", "lisas", "papaslisas", "chuguas", "rójas", "ruba" and "timbos". They resemble small potatoes and exist in several color variations. The plant itself is potato-like in general habit.

The third tuber closely resembles that of *Oxalis tuberosa* and is variously known as "añu", "mashuar", "apina-mama", "isaña" and "cubio". It is the product of *Tropaeolum tuberosum,* a twining plant resembling in foilage its better known horticultural relative. This tuber is less important to the natives than the other two, and medicinal qualities are attributed to it in their folklore. (*W. H. Hodge, Jour. N. Y. Bot. Garden 47: 214. 1946*).

Cedar Oil. In Texas there are three factories extracting cedar oil from mountain cedar [*Juniperus mexicana*] for use in perfumes, leather dressings, furniture polish and similar products. (*Anon., Texas Chemurgic News, as reported in Chemurgic Digest 5(10): 192. 1946*).

The Versatile Soybean

China's most valuable gift to the Western World—the food of millions for centuries and an ingredient in modern adhesives, plastics, foaming solutions, spreaders, waxes, soaps, linoleum, paints and numerous other industrial products.

W. J. MORSE[1]

THE soybean, the "Little Honorable Plant" of the Orient and so much in our news during the war years as the "Wonder Bean" and the "Miracle Bean", and even the theme of poems, has become one of the most valuable, if not the most valuable, of China's gifts to the people of the Western World. With its almost unbelievable number and variety of uses, it may be called the most remarkable of all plants. With an ever-expanding and amazing versatility, it has risen from an emergency crop to one of major importance, in fact, a highly essential and vital crop in our international war emergency program. It has won its way to its present recognition as a valuable aid to good farming; a commercial worthwhile crop; a useful, nutritious human food; a valuable protein feed for all kinds of livestock; and a source of raw material for numerous essential industrial products.

Nomenclature

The soybean is an annual summer legume native of southeastern Asia, and is also called the "soya bean", "soja bean" and "Manchurian bean". Botanically, the soybean usually has been referred to the genus *Glycine* and has been called *Glycine Soja* (L.) Sieb. Zucc., as well as *Glycine hispida* (Moench) Maxim. The late Dr. C. V. Piper, in an extensive botanical study, came to the conclusion that it must be named *Soja max* (L.) Piper. Other botanists, still considering the soybean to be a member of the genus *Glycine*, call it *Glycine max* (L.) Merrill. The cultivated soybean, on the basis of genetic data, is thought by many investigators to have been derived from *Glycine ussuriensis* Regal and Maack which grows wild throughout much of eastern Asia. This species is prostrate in habit of growth; has long, fine, twining stems; small, narrow leaves; appressed hairs; purple flowers; small, compressed pods; and small, oblong seeds of a sooty black color. The change from the wild to the cultivated species is thought to have occurred through qualitative and quantitative changes due to gene mutation, unaccompanied by any change in number of chromosomes. A plant with characters between the wild species and the cultivated forms has been described by a Russian botanist as *G. gracilis* Skvortzov.

History

The early history of the soybean, like that of most important food plants, is lost in obscurity. Ancient Chinese literature, however, reveals that it was extensively cultivated and highly valued as a food centuries before written records were kept. Story tellers of the Far East have related for generations, with untold variations, story-book tales of the remarkable history of the soybean. One

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of the oft-told legends and perhaps the oldest, for it undoubtedly refers to the wild soybean now found growing in the waste places of oriental countries, tells of the first use of the soybean for food. A rich caravan laden with gold and gems pulled out of an eastern Chinese village one evening, bound for a distant settlement. On the second day out in a region of mountains and waste land, the caravan was besieged by bandits. Merchants and servants took refuge in a rocky cave. When food supplies were exhausted and starvation faced the caravan, a servant ate beans from a vinelike plant. His vitality soon returned, and immediately the hopeless men began gathering and pounding the beans into a flour upon which they survived until help arrived. From then on, so the legend goes, the miracle soybean became the staff of life in China.

The soybean is said to be one of the grains planted by Hou Tsi, a god of agriculture. The first record of the plant is contained in a materia medica describing the plants of China, written by Emperor Sheng Nung, the "Heavenly Farmer", in 2838 B.C. The crop is repeatedly mentioned in later records, and it was considered the most important cultivated legume and one of the five sacred grains—rice, soybeans, wheat, barley, millet—essential to the existence of Chinese civilization. Seed of the soybean was sown yearly with great ceremony by the Emperors of China, and poets extolled its virtues. The records of ancient Chinese literature, with innumerable references on methods of culture, varieties for different purposes and numerous uses for food and medicine, indicate that the soybean is perhaps one of the oldest crops grown by man.

Engelbert Kaempfer, a German botanist who spent three years, 1690–1692, in Japan, was the first to make the soybean known to Europeans. Although Kaempfer discussed in detail the various food products prepared from the bean by the Japanese, the soybean aroused but little interest. In France the Jardin des Plantes, Paris, received in 1739 packets of soybean seed from Chinese missionaries. The Royal Botanic Gardens, Kew, England, grew soybeans as early as 1790. The plants were treated merely as botanical curiosities until the experiments by Professor Friedrich Haberlandt of Vienna in 1875 and subsequent years. Haberlandt published in 1876 the results of his investigations in much detail. Although Haberlandt strongly urged use of the soybean as a food plant for man and animals and interest was increased in its cultivation during the experiments, the soybean failed to obtain any great importance in Europe until about 1909. At that time immense quantities of beans were imported from Manchuria by several countries for the production of oil and oil meal. Through the efforts of the oil manufacturers, soybean flour found favor in the manufacture of various foodstuffs. During World Wars I and II the soybean and its products, oil and oil meal, became highly essential in the manufacture of numerous vital food and industrial products. This was especially true of Germany in World War II when soy flour was used extensively by the army in field camps. Although attempts to grow soybeans in European countries have extended over many years, in general the climatic conditions are not well suited to successful culture of the crop. At present, production is confined largely to parts of European U.S.S.R., Austria, Bulgaria, Jugoslavia, Czechoslovakia and Rumania, the largest production being in Rumania.

The first mention of soybean in American literature is by Mease in 1804 who wrote: "The soybean bears the climate of Pennsylvania very well. The bean therefore ought to be cultivated". In 1829 Thomas Nuttall grew a variety in the botanic garden at Cambridge, Mass.,

FIG. 1 (*Upper*). Wild soybean (*G. ussuriensis*) in the foreground, *G. gracilis* to the right, and the cultivated form in the background. FIG. 2 (*Lower*). A field of Patoka soybeans grown in Indiana for commercial purposes.

and from his observations wrote: "Its principal recommendation at present is only as a luxury, affording the well-known sauce, soy, which at this time is only prepared in China and Japan". The Perry expedition to Japan in 1854 brought back two varieties of soybeans which were distributed by the Commissioner of Patents. Frequent references to the plant occurred thereafter in agricultural literature under such names as "Japan pea", "Japan bean", and "Japanese fodder plant". Later, many introductions were made by several experiment stations and missionaries, but it was not until 1898 that a systematic introduction was made by the U. S. Department of Agriculture from Asiatic countries. Increase of acreage and production in the United States has been closely correlated with the introduction of varieties from the Orient and their improvement through selection and hybridization.

Present Day Production

In the Orient the soybean is grown more intensively in Manchuria than in any other country, occupying about 25% of the total cultivated area. It is a dominating factor in the economic life of the country, for as a cash crop it provides fully half of the farm income and more than half of the total volume of the freight handled by the railroads. It is estimated that from one- to two-thirds of the production of beans is exported to Japan, China and European countries, 15 to 20% being utilized for food, feed and planting, and the remaining seed employed for oil extraction.

In China the soybean ranks fifth in cultivated crops, occupying nearly 13,000,000 acres or about 9% of the total cultivated area. China consumes practically all of her production, about 220,000,000 bushels—50% for food, 27% for oil extraction and other purposes, 10% for stock feed, and 8% for planting. The quantity of beans used for oil and industrial purposes is relatively small, and exports are quite negligible. Japan and Korea are large producers, Japan consuming all of her own production and importing large quantities from Manchuria and Korea. South of China the soybean is cultivated more or less in the Philippines, Siam, Cochin China, India and the Netherland Indies.

In the Americas acreage and production are concentrated largely in the North Central States of the United States, although the crop is grown fairly extensively in the Southern States. In 1946 the twelve North Central States, with 89% (9,606,000 acres) of the total acreage produced 92% of the record seed crop of 196,725,000 bushels—Illinois, Iowa, Indiana, Ohio and Missouri being the five leading states. The phenomenal increase in acreage and production in the United States may be attributed to the following factors: improved adapted varieties; mechanization of the crop through improved machinery for seeding, cultivating and harvesting; being one of the more profitable cash grain crops; less damage from diseases and insect pests than in other common crops; being a dependable producer of forage or grain, even under adverse weather conditions; being a legume fitting favorably into corn belt rotations and crop-control programs; and available industrial markets.

The development of superior varieties for various purposes adapted to a wide range of soil and climatic conditions has been one of the most important factors in increased acreage, production and utilization of the soybean. In the breeding of varieties, as with other crops, the main objective has been increased yield. During the past few years, however, with increased utilization of the crop for food and industrial purposes, plant breeders have been called upon to give special attention to oil and protein, nu-

FIG. 3 (*Upper left*). Soybeans stored in osier bins in a Chinese merchant's storage yard, Kaiyuan, Manchuria. The soybean is a dominating factor in the economic life of Manchuria. FIG. 4 (*Upper right*). Loading bags of soybeans into a freighter at the Dairen, Manchuria, wharves for shipment to European oil mills. It is estimated that from one- to two-thirds of Manchuria's soybeans are exported to China, Japan and European countries. FIG. 5 (*Lower left*). Sprouted soybeans in a small product stall in Peiping, China. Soy sprouts afford a fresh winter vegetable rich in vitamins. FIG. 6 (*Lower right*). Combining soybeans in the Mississippi Delta. Mechanization, through improved machinery, of seeding, cultivating and harvesting the crop has been one of the principal factors in the phenomenal increase in acreage and production of soybeans in the United States.

tritive value, and quality of beans. With the development of improved varieties the importance of adaptation to different conditions has become realized by breeders. The average yield per acre in the United States has increased from 11 bushels in 1924 to 20.5 in 1946. The old standard varieties having an oil content of 15 to 18% have been almost entirely replaced by varieties having from 19 to 22%. Moreover, through introduction and selection, vegetable varieties much superior in flavor and cooking quality to the varieties used for oil have been developed. At present, about 100 varieties are available commercially, of which 72 are forage and grain types and about 28 vegetable types.

Diseases

As with most other crops in the first years of production in a new country, the soybean has been relatively free from serious epidemics of disease, except for occurrences of pod and stem blight in the Mississippi Valley and sclerotial blight in the Southern States. The record increases of soybean acreage dur-

FIG. 7. An improved variety of soybean with high seed-yield and high oil-content, developed for commercial purposes.

ing the past two or three years have, however, greatly emphasized the disease problems of the crop, especially in the large producing areas. Fields have been observed in which a large percentage of the plants has been killed by disease. Since a number of the pathogens causing soybean diseases are known to be seed-borne, increasingly severe losses must be expected if the seed sources are permitted to become more and more highly infested. Pathologists and agronomists have recognized the urgency of this disease problem and in disease surveys have found that certain diseases are increasing in prevalence and are a distinct menace to production in many localities of our large soybean region. Effective control measures for the major soybean diseases are being studied by pathologists of many agricultural experiment stations and the U. S. Department of Agriculture. It has also been found that there is more or less resistance to diseases in some varieties, thus furnishing a basis for the development of highly resistant or immune varieties by the plant breeders.

Use as Food

In oriental countries the soybean is grown primarily for the seed which is used largely in the preparation of numerous fresh, fermented and dried food products. For thousands of years the protein part of the diet of hundreds of millions of oriental peoples has been supplied or supplemented largely from soybean products. Fermented, the soybean yields all their different sauces which furnish the basic flavoring for their food; pressed, it gives oil for cooking; sprouted, it gives a fresh vegetable rich in vitamins; picked when green, it makes an excellent green vegetable; ground dry, it makes flour; soaked, ground and with water added, it provides milk, and the curdled milk furnishes the famous bean curd or tofu—the boneless meat of the Orient—used in the form of various cheeses and as a meat substitute; roasted beans are used as salted beans and in cakes and candies; roasted beans and bean flour enter into numerous health drinks; fermented bean pastes are used in soups and for preserving vegetables; and boiled beans are eaten with millet, rice or kaoliang. The soybean has thus meant bread, meat, milk, cheese and

vegetables to these people and has furnished what appears to be a well-balanced diet at a relatively low cost.

Although the many and peculiar uses of the soybean for food have long been appreciated by the peoples of Asiatic countries, it is only within comparatively recent years that it has received serious attention as such in either Europe or America. The soybean, in view of its richness in digestible nutrients as indicated partly by its unusually high percentages of protein and oil, deserves high rank as a food. European scientists for many years have realized the high nutritional value of soybean protein and fat, and Europe was one of the principal importers of soybeans from Manchuria and the United States. In 1938 one European country published an army field cook book containing nearly 300 recipes in which full fat soy flour was used to supplement meat, milk, eggs and cheese in the soldier's diet.

The importance of the soybean as an economical and valuable source of food in the human diet has become more generally recognized by the average citizen in the United States. In past years most people have looked upon the soybean as a stock feed, a crop to enrich the soil, or for processing for oil and oil meal. Extensive nutritional investigations by domestic science schools and commercial laboratories have shown that the soybean ranks higher in food value in both the green vegetable and mature stages than other beans and peas. Proteins, fats, minerals and vitamins are the most costly constituents of our diet. The high content and unique character of the protein and fat of the soybean explain in part its high nutritional value. In both the green and dry forms, it contains more fat than other legumes, but its carbohydrates are lower. It can be relied on as a good source of nutritionally important mineral elements, containing more calcium, iron and phosphorus than any of the cereals and two to three times as much calcium as other beans and peas. The calcium and iron contents of both green and dry soybeans compare favorably with any list of foods that are generally considered rich sources of these elements.

Soybean foods receiving most attention at the present time in the United States are soy flour, soy grits, soy flakes and soy meats, of which flour is the most widely used. Improvement in processing during the past few years has resulted in the elimination of the raw bean flavor so characteristic of the first soy flours placed on the American market. There are three general types of soy flour—full fat (high fat), medium fat and low fat. Full fat flour contains about 20% of oil and 40% protein; medium fat, 5 to 7% oil and 45 to 48% protein; and low fat, approximately 1% of oil and 50 to 53% protein. Primarily a protein concentrate, soy flour's principal function is to add nutritive value to other foods. Soy flour, soy grits and soy flakes are used with wheat flour in bakery goods, macaroni and other paste goods, soups, candies, ice cream powders, prepared baking mixes, breakfast foods and confections, and as an extender in various meat products. Soy flakes have been used to some extent in the brewing of beer. Soy meats are split or coarsely ground soybeans, dehulled and debittered, and are used in place of roasted nuts in confections. Other food products now on the market are baked beans, canned and quick-frozen green vegetable beans, salted roasted beans, breakfast foods, soy butter, candies, chocolate, curd or cheese, diabetic foods, flavorings, health foods, cones, meat-like products, milk substitute (liquid and powder), soy sauce, soups, sandwich spreads and infant foods.

Vegetable varieties of soybeans, now available in all sections of the soybean-growing region, have become quite popu-

FIG. 8 (*Upper*). Brewing soya sauce in the yard of a soya sauce factory, Peiping, China. Fermented, the soybean yields a variety of sauces which furnish the basic flavoring agent for oriental foods. FIG. 9 (*Lower*). Soybean curd, the boneless meat of the Orient, used as a meat substitute and in the form of various fermented cheeses.

lar as green-shelled beans used in the same manner as green peas or lima beans. These varieties are much superior in flavor and cooking quality to the varieties used for processing for oil and oil meal. Many of them are handled by growers and seedsmen and are being used extensively for green vegetable beans in home gardens and by canning and quick-freezing companies. The soybean has been used in the United States primarily as a forage crop, being preserved as hay or silage or cut and fed as soilage. It is also pastured with hogs and sheep quite extensively in some sections and is used as a green manure or cover crop, especially in the sugar cane areas of Louisiana.

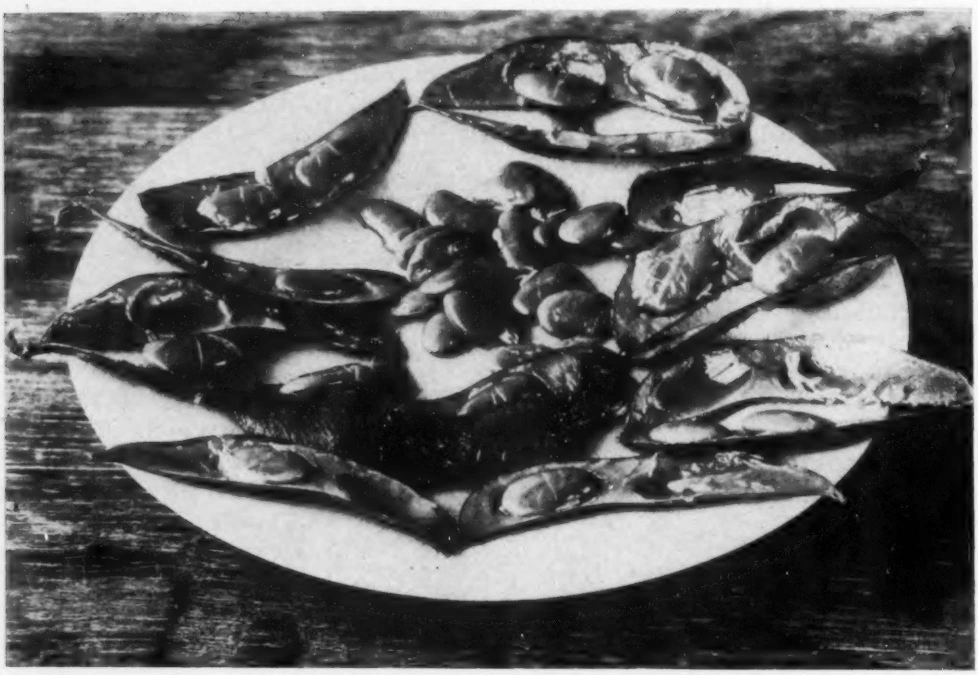
Use as a Source of Oil

In addition to its forage and food values, the soybean contains a valuable oil. About 1920 the production of soybeans greatly exceeded the requirements for planting, and several oil mills in the Midwestern States became interested in the possibilities of the soybean as an oil seed; by 1929 oil mills were a potent factor in the production of the crop for commercial purposes. The soybean now appears firmly established in the industrial world, and the oil produced has come to fill an important place in the domestic vegetable oil supply and economy. In the early part of 1944 nearly 100 oil mills, specializing in soybean processing, were operating in the United States. These mills, located at 80 points in 18 states, had a crushing capacity of about 130 million bushels per year. In addition, more than 100 other oilseed mills, mostly cottonseed mills, were crushing temporarily or only part of the time. Late in 1944 there were 137 soybean-processing mills, counting those under construction and those definitely planned with priorities approved. The total annual capacity of these mills was estimated at 172 million bushels. The scale of processing operations expanded rather slowly at first, but as larger supplies became available, processing greatly increased. In the period 1924–1925 only 307,000 bushels of soybeans were crushed, but in 1943–1944 142,258,000 bushels of a total production of 193,125,000 bushels were processed.

The three methods in general use for obtaining oil from soybeans are hydraulic pressing, expeller or screw pressing, and solvent extraction. Expellers or screw presses handled 74% of the soybeans processed in 1940–1941, and solvent extraction about 23%. There has been a rapid expansion in processing capacity for both expeller and solvent types of plants since the middle of the 1930's. The rate of expansion of solvent processing has been the greater of the two.

The yield from a bushel (60 pounds), on the average, processed by an expeller press is about 9 pounds of oil and 48 pounds of meal. The meal contains from 40 to 45% protein and 4.0 to 5.5% oil. The average yield from a bushel of soybeans processed by the solvent method is about 10.5 pounds of oil and 45 pounds of meal. Solvent process meal contains 43 to 48% protein and 1% or less oil. Variations from these averages may occur to a considerable extent in individual cases because of differences in oil and protein content of different varieties and of the same varieties grown in different localities, and because of the differences in efficiency of operation of individual plants.

Soybean oil has qualities that make it adaptable to a wide variety of uses. It is classed as a semi-drying oil, and its fatty-acid composition is another quality which gives it versatility. During the past 30 years the principal use made of soybean oil has been at times in soap, at other times in the drying industries, and most recently in food products. Much progress has been made during the



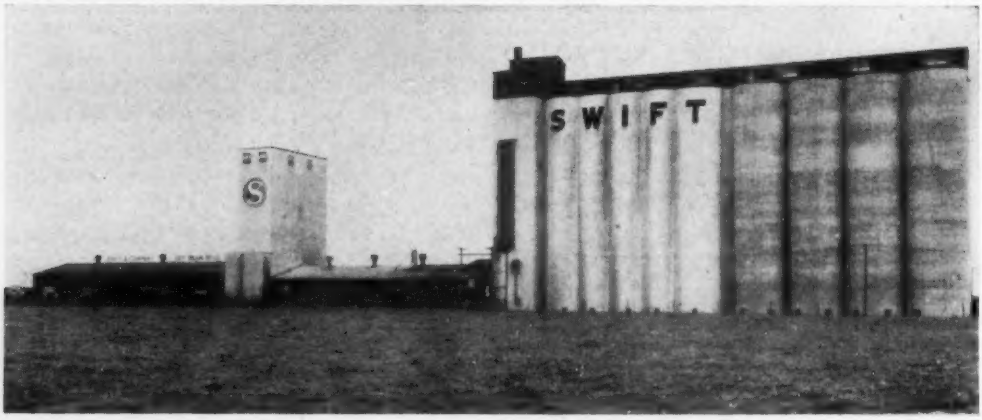


FIG. 10 (*Upper*). Vegetable soybeans, now available in all sections of the soybean-growing region in the United States, have become quite popular as green shelled beans. They are extensively grown as such and are used by canning and quick-freezing companies. FIG. 11 (*Lower*). In 1944 there were 137 soybean-processing mills in the United States, the combined annual capacity of which was estimated at 172 million bushels. More than 142 million bushels of the total production of 193,125,000 bushels were processed during 1943–1944.

last decade in methods of refining, bleaching and otherwise improving the oil for food uses. In 1939 soybean oil comprised 5.6% of the total production of fats and oils, including butter, lard, tallow and all vegetable oils, for domestic materials in the United States, and in 1943 the proportion accounted for by soybean oil was 11.4%. More than 50 different food products containing soy-

bean oil are manufactured in this country; the principal food use at present is for shortening. In 1943 soybean oil made up 42% of the total oils and fats used in shortening, 40% in margarine and 16% in other edible products. Other products using the oil include soaps, cleaning compounds, disinfectants, lecithin, insecticides, foundry oils, paints, enamels, lacquers, varnishes, linoleum, oilcloth, printing ink, oil clothing, resins, grease and lubricating compounds, rubber substitutes, patent and artificial leather, waterproof goods, candles, medicinal oil, sticker for lead compositions, textiles and sulphonated oils.

Soybean Meal

Soybean oil meal remaining after processing the beans for oil is a most valuable product and has wide usefulness. Production of soybean oil meal in the 1920's (1924–1925, about 8,000 tons) was small, but production increased rapidly the following years. In 1938–1939 it was 140 times as great as in 1924–1925, and in 1943–1944 (nearly 3½ million tons) was more than three times that in 1938–1939. Soybean oil meal, a highly concentrated and nutritional feed and food, is and has been extensively used for all kinds of livestock in American and European countries. It has been gaining favor among livestock feeders for several years. It is estimated that from 90 to 98% of the total domestic disappearance has been for this use. Less than 1% of the production of soybean meal was used in making soy flour in the years immediately preceding World War II. Soy flour manufacture greatly increased during the war, the quantity produced in 1943 being equivalent to about 3% of the total soybean crop. Foreign governments purchased large quantities of soy flour and other soy proteins to fortify bread and various products. Industrial products, in which the oil meal or protein is used, include adhesives for plywood, molding compounds, core binder compounds, plastics (especially in the automobile and electrical appliance industries), paper coatings, paper sizing, cold-water paints, foaming solutions, pollen supplement for bees, textile fiber (vegetable wool), spreaders for insect sprays, finishing waxes and waterproofing for textiles. Substantial tonnages of soybean meal were used in the manufacture of mixed fertilizers before the war, but this was not permitted during the war. In oriental countries the oil meal is used very extensively for fertilizing purposes—rice and various truck crops—and also to some extent as livestock feed.

A comparative newcomer in our midst, the soybean has found a vitally important and almost indispensable place in our agricultural and industrial economy. From the status of a little-known oriental plant it has become a crop of high economic importance, and at the time of our greatest need, due to the exigencies of war, it has proved its unique usefulness as a source of highly nutritious food and feed and of an almost limitless variety of industrial products.

Utilization Abstracts

Tree Bark. The great Weyerhauser Timber Company of Longview, Wash., has announced "that commercial processing of the bark of Douglas fir and other trees is about to begin in a factory now being built there. The bark will be made into several materials of different usages, among them being a plastic, a glue, and a component for insecticides". (*Chemurgic Digest 5(13): 222. 1946*).

The Production of Minor Essential Oils in the United States

The oils of dill, lemon-grass, tansy, wormseed and wormwood are distilled from cultivated plants; those of cedarleaf, cedarwood, erigeron, pennyroyal, sassafras, sweet birch, wintergreen and witch-hazel from wild plants; and together they all constitute a minor industry for which production figures are not readily available.

A. F. SIEVERS[1]

Introduction

THE production of essential oils in the United States is a relatively broad subject which may be discussed from several standpoints. There are the oils that are produced from imported materials by those who specialize in the production and marketing of essential oils for the consuming industries. This phase of essential oil production has no interest for persons concerned with the utilization of native domestic plants for this purpose or the cultivation of aromatic plants as sources of such products. The present paper deals entirely with the production of oils from plant material of domestic origin. A discussion of the subject on this restricted basis requires a further rough division of the oils into two groups, namely, those produced on a relatively large scale, and those that are of relatively minor inportance from the standpoint of their economic value and the bearing their production has on the nation's economy. In the first group are turpentine, the production of which is a part of the naval stores industry of the southeast; mint oils, produced in the North Central and Pacific Coast States; and citrus oils, produced as by-products of citrus fruits in the citrus-growing regions of the South and West. Adequate information concerning the production of these oils is quite generally available. In the second group of oils are several distilled from cultivated crops and others obtained from wild plants. The oils included in this group are in no case produced in large amounts, and their production offers very limited opportunities to additional farmers and landowners, since most of them have very limited and specific uses.

As the title suggests, this paper deals with the production of these minor oils. Five of them are obtained from cultivated plants, namely, wormwood, wormseed, tansy, dill and lemongrass. The remainder, cedarleaf, cedarwood, sassafras, erigeron, pennyroyal, wintergreen, sweet birch and witch-hazel, are distilled from wild plants. Information on the production of these oils from both cultivated and wild plants is very meager. Agricultural census reports sometimes include statistics on acreage and production of some of the cultivated species, but for the years between the publication of these reports production figures can be obtained only by local investigations and inquiries. Oil production figures are altogether lacking for the wild species. The year to year production is

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probably known quite accurately by the trade, but there are no published statistics.

Oils Distilled from Cultivated Plants

With the exception of lemongrass and dill, the oils obtained from cultivated plants have been produced for many years, usually in restricted areas. Wormseed is produced only in central Maryland where this crop has been grown for more than a hundred years. Wormwood has long been a minor crop on a few mint farms in Michigan, Indiana and Oregon. Dill oil is a comparative newcomer, since the substitution of dill herb oil for the herb itself in the flavoring of pickles is of fairly recent origin. The most recent introduction in this group is lemongrass oil which is now the product of a single producer in Florida.

Wormwood. This oil is obtained by distillation of the perennial herb *Artemisia Absinthium* L. Its production in recent years has been confined to southwestern Michigan where about 500 acres of the crop are grown on black muck soil in St. Joseph and Cass counties, and western Oregon where 27 acres were grown in 1939, according to the U. S. Census 1940. The crop is grown mainly by producers of mint oil. The plants are started in seedbeds in spring for fall transplanting to the field or in fall for spring or summer transplanting. The soil in the seed bed must be well prepared and in fine tilth, and the seed scattered evenly on the surface and left uncovered. Most growers prefer to transplant the seedlings when they are five or six inches high, but smaller and much larger plants can be used. The seedlings are loosened with a fork, lifted from the ground, gathered and tied into large handfuls. When the plants are rather large the tops are cut off on a chopping block with a sharp knife or hatchet. The bundles are then dipped in water and placed close together in a

FIG. 1. Wormwood (*Artemisia Absinthium*). (*From Stephenson & Churchill, Medical Botany, 1835.*)

crate in which they are taken to the field. The planting is done with celery or mint transplanting machines. At present-day farm wage scales it costs about $30 to $35 to grow the seedlings for one acre and set them in the field. Cultivation sufficient to control weeds is required, and hand weeding is generally necessary if the field is to remain productive for several years. The more successful growers use fertilizers, usually a fall

FIG. 2. Tansy (*Tanacetum vulgare*). (*From Stephenson & Churchill, Medical Botany, 1835.*)

application of 3–12–12 and about 200 pounds of ammonia nitrate per acre in the spring.

Wormwood is harvested when in the early-to-full bloom stage. A grain binder pulled with a tractor with a power take-off is used. The wormwood stems are coarse and tough, hence the extra power required. The bundles are put in small shocks and allowed to cure for several days after which the oil is distilled in mint-distilling equipment. The yield varies greatly, ranging from seven or eight pounds per acre from poor fields to as high as 40 pounds in exceptional cases. On the average, 20 or 25 pounds may be expected if the crop is well handled and the season is favorable. If the weeds are well controlled a wormwood field remains productive for several years. The crop does not appear subject to serious diseases or insect pests.

Practically all growers of wormwood produce the oil under contract extending over five to ten years. The oil has only one important use, namely, as a therapeutic component of a liniment for man and animal. The manufacturers of this liniment provide the contracts for the growers. Since there is no outlet for the oil for other purposes, production in excess of the quantity contracted for is inadvisable. There is therefore no opportunity for any considerable increase in wormwood acreage in the regions where it is now grown or for its introduction elsewhere in the country.

Tansy. Like wormwood, tansy (*Tanacetum vulgare* L.) is also a very minor crop on some mint farms. Buyers of this oil report that the average annual production is not more than 1,000 pounds. This amount is obtained from about 100 acres in southwestern Michigan and northern Indiana. In 1946 about 60% of the acreage was on a single large mint and truck farm in Michigan.

Tansy is not a very popular crop. The market demand for the oil is limited because it has only a very limited use in medicine, and the price fluctuates greatly, having ranged from as low as $2.00 to $9.00 a pound. One reason the crop is grown at all is that once established it will continue productive for years.

The crop is started by setting the field

with young plants five to six inches high, pulled from established fields and set in rows three feet apart with transplanting machines. The usual cultivation and some weeding is necessary the first season, but the plants spread rapidly and broadcast over the field in a year. Thereafter, due to the dense growth, weeds are largely suppressed. The crop when in bloom usually is harvested with a grain binder. If labor is available the bundles are placed in shocks; otherwise they are left on the ground to cure. One grower cuts his crop and cures it in the swath like mint. It has to cure somewhat longer than mint before being distilled due to the heavier stems.

Wormseed. The volatile oil of American wormseed, *Chenopodium ambrosioides* L. var. *anthelminticum* (L.) Gray, has been produced from this cultivated plant without interruption for more than a hundred years in Carroll and adjoining counties in central Maryland. The reason why this small special industry has never shifted to other regions is not known. The plant is adapted to a rather wide area, and experiments have shown that it can be grown elsewhere. Here again is a product used only for one purpose. It is an efficient vermifuge, due to its principal constituent, ascaridole. For a long time it has been a most important therapeutic agent for the control of certain intestinal parasites. For many years, however, it has to some degree been replaced by carbon tetrachloride. As is always the case with crops yielding products of limited use, overproduction has frequently occurred, especially following years when the price of the oil was attractive. The market value of the oil has fluctuated greatly but not entirely due to supply and demand. In some seasons, for reasons not always understood, the oil has been low in ascaridole content with a corresponding reduction in value.

FIG. 3. Mexican tea. (*Chenopodium ambrosioides*). (*From Degener, Flora Hawaiiensis, 1934.*)

Although this crop is grown in such

a limited area statistics on acreage and production are not always available. According to the Agricultural Census of 1940, the production in 1939 was 38,281 pounds by 240 growers on 927 acres. Later figures are not available. The seed is sown early in spring in outdoor seedbeds much like tobacco seed. When the seedlings are four to five inches tall they

FIG. 4. Dill (*Anethum graveolens*). (*From Esenbeck Plantae Officinales, 1828.*)

are set in the field with tomato planters in rows so spaced that the usual farm cultivation implements can be used. The type of plant grown is shorter and bushier and produces more seed than the wild form. Since the covering of the seed contains a high percentage of oil this type yields more oil per acre. In early fall the crop is harvested with a mower with a buncher attachment, as used for seed clover, and allowed to dry partially before it is distilled. The yield of oil obtained ranges from 10 to 40 pounds per acre.

The quality of wormseed oil depends on its ascaridole content which is easily affected by several factors. If the crop is harvested when too immature the ascaridole content of the oil is low. The temperature of the condenser water and the rate of distillation must be carefully controlled. Under certain conditions ascaridole is quite soluble in water, and some producers redistill the distillate water and thus recover much of this important constituent.

Dill. The dill herb obtained from *Anethum graveolens* L., which is so widely used for flavoring pickles, consists of the leaf, small stems and seed, the latter in various stages of maturity. The successful use of dill oil as a substitute for the herb requires that the oil possess the same flavor as the herb. Since the leaf oil and seed oil are quite different it is essential that the oil be distilled from herb harvested at the stage at which it is used for pickling. To accomplish the harvesting and distillation at exactly this stage is therefore a chief concern of the grower.

Dill oil was first produced in the North Central States about 15 years ago in response to the demands of pickle and kraut manufacturers. Ohio, Indiana and Michigan have been the principal centers of production, but in recent years the production has shifted to Oregon and Idaho. For several years the center of production was in the vicinity of Berne, Indiana, where up to 500 acres of dill were grown and six or seven stills were in operation. At that time the growers received \$4 to \$5 a pound under contract. A decline in price resulted in a gradual reduction in acreage until at the present time only about 5% of the former acreage is grown there. Information on

the acreage in the Northwest is not available, but at present the principal production of the crop is apparently in the Willamette Valley in Oregon.

In Indiana dill is sown directly in the field with a beet or bean drill early in spring in rows about 22 inches apart. The crop is ready to harvest in 90 to 105 days. It is harvested usually about the middle of July when the earliest seed has ripened, using a grain binder. The herb is allowed to cure in the field for a day or two and then distilled with the same equipment as is used in distilling mint. It requires from 2½ to 3 hours to exhaust the charge. The yield ranges from 15 to 50 pounds per acre. At times a second crop is obtained the same year, but the yield is small and usually unprofitable. There are several varieties of dill, some of which are not suitable for the purpose because they yield less oil or oil of poor quality.

Japanese mint. A variety of mint, *Mentha arvensis* L. var. *piperascens* Malinvaud, which for years was grown almost exclusively in Japan and is hence called "Japanese mint," is the only commercial source of natural menthol in normal times. During the recent war this mint was grown extensively in Brazil, and it remains to be seen which of these countries will become the principal supplier of menthol in the future.

This variety of mint is closely related to the peppermint grown in this country, but it produces an oil with up to 80% of menthol and which is therefore a much better source of this product than the American peppermint oil with only 50% of menthol. The species was grown successfully in California about 20 years ago when the high price of menthol made the crop profitable. During the recent war, when menthol was once more of high value, it was again introduced into that State in the general vicinity of Shafter where it was also grown previously. However, interest in the crop could not be sustained when greatly increased Brazilian production of menthol and the end of the war clearly pointed to an early decline in the price of that product.

The Japanese mint is less hardy than American mint and is therefore not so well adapted to the mint-growing sections of the North Central States. Experimental plantings in many parts of the country have shown that the menthol content of the oil is generally highest when the crop is grown in the northern States and in California. The plant grows vigorously under irrigation in California and produces two cuttings a year. The yields of oil average 60 to 70 pounds per acre and are larger than elsewhere, and since the oil contains about 80% of menthol the crop is undoubtedly best adapted to that State. The higher returns more than offset the higher cost of production.

The crop is grown and distilled like American mint. Extracting of the menthol from the oil is accomplished by refrigeration which causes the menthol to crystallize. The oil is separated from the crystals with a centrifuge and then again refrigerated, and the process thus repeated several times. The dementholized oil is poor in flavor and not generally acceptable for the purposes for which American peppermint oil is used. The Food, Drug and Cosmetic Act requires that goods flavored with Japanese mint oil or the dementholized oil be labeled "flavored with corn mint." It is not practical for the average grower of this mint to undertake extraction of the menthol, and the general practice has been for the growers to sell the oil under contract to the principal consumers of menthol or to dealers in oils who have the facilities for economic separation of the menthol.

Lemongrass. On the reclaimed land of the Everglades in southern Florida there is at present the only acreage in this country of a true tropical essential

oil plant. The United States Sugar Corporation has more than 1,000 acres of lemongrass, *Cymbopogon* sp., under cultivation at Clewiston. Lemongrass oil is widely used for scenting soap and cosmetics, and it is a principal source of several products important in the manufacture of perfumes. Its production in Florida by the company mentioned has some interesting economic aspects. The growing, harvesting and distilling of this crop that is gathered several times during the year absorbs much labor that must be kept on hand for handling the sugar cane crops but which is available for other work at certain periods. The spent grass is combined with low grade molasses from the sugar factory to make a stock feed. With this economic use of labor and the utilization of what would otherwise probably be a waste product the production of this oil was believed to be commercially feasible.

The first published reports on the introduction of the crop at Clewiston record calculated yields of 150 pounds of oil per acre from experimental plots obtained from three cuttings during the period from June to October. At that time the oil was selling for around $4.00 a pound. Thereafter the price declined, and at the same time the cost of labor increased. In a second report in 1945 it is emphasized that although the industry is highly mechanized the higher labor cost made the crop unprofitable at the oil price then prevailing. The per acre yields obtained from between 1,100 and 1,900 acres during the period September, 1941, to February, 1944, were considerably less than that indicated by the test plots, but more than 100,000 pounds of the oil were supplied to domestic consumers during that period.

Oils Distilled from Wild Plants

The production of essential oils from wild plants in the United States is a very limited industry from the standpoint of total output and persons employed. However, the oils thus obtained have for many years found very specific uses in the manufacture of many products. With the exception of cedarwood oil these oils are produced to a large extent by relatively crude methods, frequently in migratory stills moved from place to place as the supply of raw material is exhausted. Production is more or less sporadic, depending on the market value of the oils and the availability of labor. All these oils are produced in the eastern and southern section of the country and the majority in the mountain regions of the New England and Middle Atlantic States.

Cedarwood. The oil of the red heartwood of Virginia red cedar, *Juniperus virginiana* L., has long been valued as a moth repellent, which fact is the basis of the use of red cedarwood in the construction of clothes chests and closets. The oil is used for impregnating garment bags, is a component of cleansing and polishing liquids, furniture polish and sweeping compounds and is used in the scenting of soap.

Until recent years cedarwood oil was produced entirely as a by-product in the manufacture of cedar lumber, cedar chests, pencil slats and other cedarwood products. Utilization of red cedar sawdust and other wastes for this purpose has at one time or another been a definite part of the operations of half a dozen or more manufacturers of cedarwood products in southwestern Virginia, western North Carolina, Kentucky, Tennessee and Florida. Virginia red cedar stumps and roots and old fence rails of the same wood are also frequent sources of the oil. Production of the oil has been sporadic, as its price has fluctuated over a wide range due to overproduction and various other reasons.

To distill the oil with steam in conventional distilling equipment it is necessary to reduce the waste wood stumps or other

large-sized material to very small particles. First it is passed through a hogging machine in which it is chopped into thin pieces up to ten inches in length. A hammer mill then reduces these to a coarse powder that is then loaded into the still that holds from 3,000 to 5,000 pounds. Distillation is conducted as with other oils, but eight hours is usually required to exhaust the charge. The water that flows from the receiver is generally conducted into a second receiver where a small additional quantity of oil is obtained that is redistilled, resulting in a water-white oil known in the trade as "double-distilled". The yield of oil obtained depends on the proportion of red heartwood and sapwood used. The heartwood may yield up to 4% of oil, whereas sapwood generally yields less than 1%.

During the past 15 years there has been a gradual development of a cedarwood oil industry in Texas. After repeated failure for one reason or another the industry in that State now appears to be well established, and several producing plants are now in operation in as many localities. It is reported that production of the oil in the older producing centers has largely ceased and that production has shifted to Texas. The Virginia red cedar is not abundant in Texas, and most of the oil now produced there is obtained from two other species, *Juniperus Ashei* Buchholz and *J. monosperma* (Engelm.) Sarg., that occur in varying abundance over several million acres. These species are removed in land clearing operations and cut into posts or merely burned. The cost of producing the oil from this material and from stumps, it is claimed, is greater than that of producing it from the waste sawdust and other material resulting in the manufacture of cedarwood products in the Southeast, the securing of which involves no labor costs.

Details of the present operations in Texas are not available, and reports of complete examinations of the oil from the Texas species other than *J. virginiana* have not appeared. It is generally known that the oil from these is different in some respects from that obtained in the Southeast, and it may be assumed that these several oils are not entirely interchangeable in all their uses. However, the fact that Texas is at present the principal geographic source of cedarwood oil suggests that the shift in the industry may be permanent. Production costs and the availability of supplies of the wood in one form or another will no doubt be important factors in determining the future status of this industry. Several hundred thousand pounds of the oil have usually been produced annually in this country.

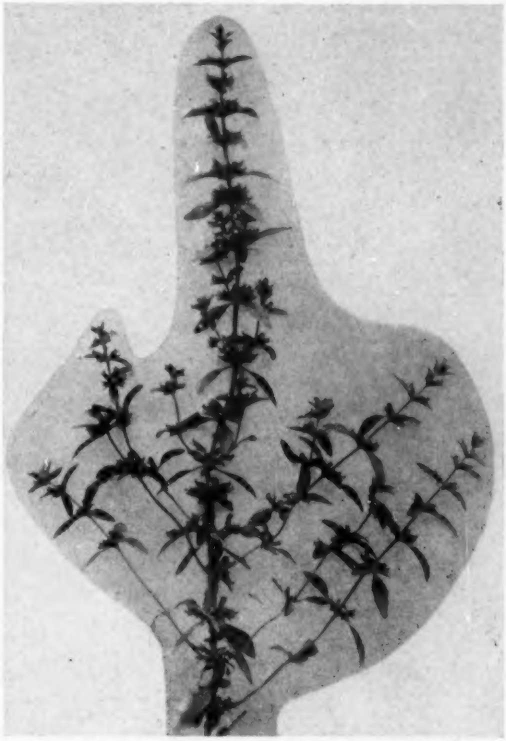

FIG. 5. Pennyroyal (*Hedeoma pulegioides*). (*Courtesy U. S. Bureau of Plant Industry.*)

Pennyroyal. Small amounts of pennyroyal oil have been produced in Ten-

nessee, North Carolina and other States from wild plants of *Hedeoma pulegioides* (L.) Pers., but its production gives so little promise of profit that attempts to produce it are frequently soon abandoned. The high cost of collecting large quantities of scattered, wild growing plants is no doubt the principal reason. The operations are so sporadic and the amount of oil produced is so limited that no reliable information or statistics concerning the subject can be obtained.

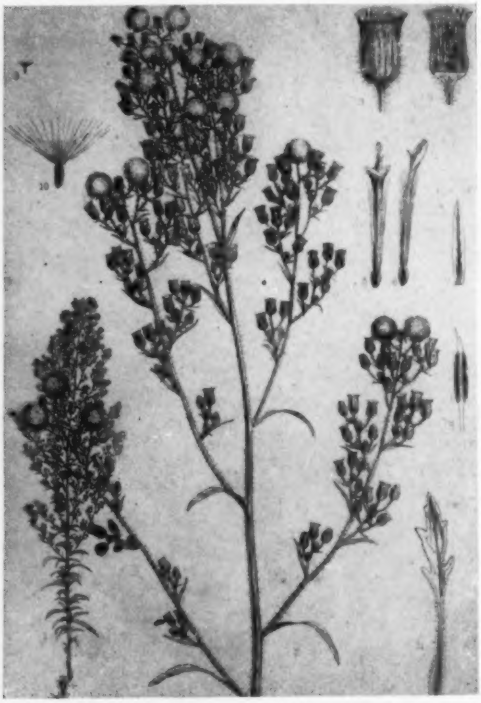

FIG. 6. Fleabane (*Erigeron canadense*). (*From Bentley & Trimen, Medicinal Plants, 1880.*)

Erigeron. The prolific weed *Erigeron canadensis* L., common in abandoned corn and other fields in the Middle West where it is known as marestail, is the source of small quantities of erigeron oil distilled by mint farmers from time to time in southern Michigan and northern Indiana. The oil finds a limited use in pharmaceutical preparations. Production is extremely sporadic, and no statistics concerning it are available. The plant is never cultivated, but when it grows very abundantly in a field in the mint or wormwood growing section the "crop" is likely to be bought for a few dollars by somebody who owns a still, and the oil distilled from it. The buyer harvests it with a binder or mower, allows it to dry several days and then distills it. The yields are reported to be from 25 to 30 pounds per acre when the stand is heavy.

Sassafras. The common sassafras *Sassafras albidum* (Nutt.) Nees, widespread and abundant on waste lands in the eastern third of the country, is the source of sassafras oil. This oil is widely used as a flavor in carbonated beverages and dentifrices and for its medicinal properties in some pharmaceutical preparations. It is produced mainly in various sections of Kentucky, Tennessee, North Carolina, Virginia and southern Indiana and Ohio. All parts of the sassafras tree contain the oil in varying quantities, but only the roots and stumps are utilized. Some of the oil is distilled in small, rather primitive stills which are probably moved from one location to another as new supplies of the needed material must be found. There are several larger operators with more modern stills. The raw material for these is obtained either from farmers who secure it on their land and deliver it to the still or through the distiller's collection crews who are provided with the necessary equipment. The trees are felled and the stumps then pulled out of the ground. They are cleaned of adhering dirt and hauled to the distillery where they are run through a hogging machine and reduced to small chips which are stored above the still into which they are loaded as needed. The bark of the root contains from 5 to 9% of oil, whereas the wood contains less than 1%. When the sap is flowing in the spring or when the ground

is frozen, much of the bark will strip from the roots and remain in the ground when the stumps are pulled. It is the practice, therefore, to engage in this operation in late summer or fall. Distillation is conducted in the usual way. Steam is admitted from a boiler and blown through the chips in the still. The operation is completed in about four hours. The yield of oil varies from 1.5 to 2%, according to the proportion of wood and bark in the charge.

Cedarleaf. In northern New York, Vermont and to a less extent in New Hampshire and Maine the production of cedarleaf oil has long been a small local industry carried on by farmers during the time of year when they are not occupied by usual farm work. The oil, used for general scenting purposes, is obtained from the leaves and small branches of the white cedar, *Thuja occidentalis* L., abundant in that region. With few exceptions the distillations are conducted with rather crude equipment, mostly constructed from materials locally available and at small cost. They are of the type where steam is admitted into the still from an outside source and no fire is maintained under the still. Old saw mill or hoisting engines are generally used as a source of steam. The stills are set up near springs or streams which provide ample water for the condenser through gravity flow or by means of pumps.

The most desirable material for distillation consists of the leaves and small branches removed from trees about five feet in height. Such material is reported to yield from 1 to 1.5% of oil. It is cut up into small size and packed tightly in the stills. These are in most cases made of spruce planking, tongued and grooved. The seams are calked with clay or other suitable material. Some producers use steel tanks. The stills are operated by admitting steam into the tub directly from a boiler.

The equipment is moved from time to time, sometimes to several locations within a season. This is necessary to avoid hauling the brush long distances. The small trees are brought to the still where the usable material is trimmed off. The heavy wood furnishes fuel for the boiler. The spent material after drying is also used for fuel. About five years is required for new growth to reach the desired size.

Procuring the material for the stills involves hard labor which is often performed under severe weather conditions. Considering the labor involved, the returns are relatively small, but they provide additional income without undue interference with the usual farm operations.

The oil is usually brought by the producers to local storekeepers or collectors in some central location where it is cleaned by removal of dirt and water before entering the market. Some producers, however, sell directly to large dealers in essential oils.

Sweet birch and wintergreen. Two native plants yield volatile oils of identical flavor, namely, sweet birch and wintergreen. These oils consist of up to 99% of methyl salicylate to which the therapeutic properties of the oil are due. Methyl salicylate can be made cheaply synthetically, and since it has the same medicinal properties as these natural oils, the U. S. Pharmacopoeia permits its use for medicinal purposes, provided it is labeled accordingly. However, the oils possess certain flavor characteristics not possessed by methyl salicylate, and they therefore are in demand as flavoring agents in certain products. They are used in carbonated beverages, chewing gum and dentifrices. For their therapeutic value they may be used in liniments and ointments, but for that purpose they are probably not superior to methyl salicylate. Neither sweet birch nor wintergreen oils exist in the respective plants as such but are formed when

certain glycosides that are present are acted upon by plant enzymes. To bring about this reaction the plant material used is chopped or crushed and then macerated in warm water in the still, generally overnight, before the usual distillation is started.

The sweet birch or black birch, *Betula lenta* L., is a rather widely distributed tree from New England to Tennessee and Florida. Production of the oil is a very limited industry, carried on chiefly in north central and eastern Pennsylvania,

FIG. 7. Black birch (*Betula lenta*). (*Courtesy New York Botanical Garden.*)

the Connecticut Valley and in the southern Appalachian region of Tennessee and the Carolinas. The trade recognizes two grades of the oil, namely, northern oil produced mainly in Pennsylvania and regions north, and southern oil, produced in the region farther south. It is claimed that the northern oil has a superior fragrance. This preference is reflected in the market value of the two grades. No botanical differences can be discerned between the trees in the two regions, and the physical and chemical characteristics of the oils from the two regions do not provide a basis for this distinction by the trade.

Production of birch oil in five north central Pennsylvania counties is largely a winter activity of farmers in that region who thus utilize the otherwise slack period on the farm to add to their income. The cutting, hauling and trimming of the branches is a laborious task, somewhat less so in winter because it is not hampered then as in summer by the leaves which do not contain oil and only add to the amount of material that must be handled. It is impractical and uneconomical to haul the material more than a few miles, and many of the stills are therefore moved from place to place. Several years are required for the new growth on the cut trees to reach the desired size.

The stills, which are of about 200 cubic feet capacity and hold from 1 to $1\frac{1}{2}$ tons, are constructed of heavy planks made as leak-proof as possible. The bottom is faced with heavy sheet copper so that a fire may be maintained directly under it. The stills are firmly packed full with the small material at the bottom.

If the period of maceration is during the night, distillation is conducted through most of the following day. The yield approximates 0.5% of oil. The oils are heavier than water and therefore settle to the bottom of the receivers which must be designed accordingly. The water which flows from the receivers during the early period of the distillation holds considerable oil in suspension, and this is generally returned to the still with the next charge.

Production of the so-called southern oil is no doubt accomplished in much the same manner. There the distilling equipment is likewise of simple and inexpensive design, and, as in the north, stills are moved from place to place to be accessible to the material needed.

Wintergreen, *Gaultheria procumbens*

L., is a small, low growing, perennial, evergreen herb usually found in cool, damp situations in woods, most abundantly in the mountains of the Eastern States. Production of the oil is centered in Carbon and Luzerne counties, Pennsylvania. Collection of the herb is slow and difficult. The plants are usually partly covered with fallen leaves which must be raked off after which the leaves and small stems of the wintergreen are pulled off by hand and placed in sacks. Since much of the work is under low growing trees its laborious nature can easily be understood. The distillation is usually done in the summer months when the plant contains the most oil and children can be helpful in collecting.

The oil, which is the same as birch oil, as already explained, is obtained by maceration and distillation with the use of similar equipment, similarly operated but generally of smaller size. Most of the stills are of simple, home construction, but there are several of more advanced design. The time required to exhaust a charge is reported to range up to 12 hours. The yield of oil depends on the season of the year, the proportion of leaves and stems and the completeness of the chemical reaction that takes place during the maceration. The average is about 0.5%. The amount of oil produced annually has decreased steadily for years, and at present only a few people are engaged in its production.

FIG. 8. Wintergreen (*Gaultheria procumbens*). (*Courtesy U. S. Bureau of Plant Industry.*)

FIG. 9. Witch-hazel (*Hamamelis virginiana*). (*Courtesy Mass. Hort. Soc.*)

Witch-hazel. Although the witch-hazel shrub, *Hamamelis virginiana* L., contains a volatile oil which has for many years been considered the therapeutic agent in witch-hazel extract used in external medicine, the oil is not produced as such. The product obtained in Connecticut from the witch-hazel shrub is the aqueous distillate resulting from steam distillation of the young branches. To this 15% of alcohol is added. It is an official product of the National Formulary VII in which it is described under the names "witch-hazel water",

"Hamamelis water" and "distilled extract of witch-hazel". No oil separates during the distillation.

There are no farmer producers operating crude equipment, as in the case of most of the oils already discussed. The industry in south central Connecticut is limited to the operations of a few special producers with highly developed modern copper stills using selected raw materials. It is reported that generally 50 gallons of filtered aqueous extract are obtained from 1,000 pounds of brush. To this the alcohol is added, and the product is then stored in oak barrels which are paraffined on the inside. There are no statistics on the quantity of the extract produced.

Acknowledgments

The information for the foregoing discussion was derived from various sources. Some of it is based on correspondence with producers, and credit is due to those who thus contributed to this paper. Dealers in essential oils aided greatly by furnishing the names and locations of producers. Unpublished reports of field investigations of essential oil production made by members of the division at various times were consulted. As stated in the introduction, statistics on the production of these oils are almost entirely lacking. Such figures as can be obtained from various sources are usually incomplete or contradictory and more misleading than useful. The literature on the subject is limited, and some of it is old and unreliable, but much useful information was nevertheless obtained from such sources.

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Utilization Abstracts

Pineapples. Pineapples have previously been reported as growing wild in Brazil, Surinam and Paraguay, and now there is word of their wild state in Venezuela. The forms there bear seeds abundantly and occur in a number of varieties, some of which have been under cultivation by the Piaroa Indians. (*Ismael Vélez, Science 104: 427. 1946*).

Tung Oil—*A Gift of China*

In 1937 the annual maximum of 175 million pounds of this valuable drying oil was imported from China into the United States, and by 1946 constantly increasing domestic production of the oil rose to a little more than 15 million pounds that year.

G. H. BLACKMON
Florida Agricultural Experiment Station

Introduction

IN 1905 the United States Department of Agriculture brought the tung-oil tree, *Aleurites Fordii,* from China to the United States and thereby initiated one of the many attempts that have become so important in recent years to make America independent of foreign sources of plant products. The genus *Aleurites* contains five species, *viz., A. Fordii* Hemsl., *A. montana* (Lour.) Wilson, *A. moluccana* (L.) Willd., *A. cordata* Thunberg and *A. trisperma* Blanco, but of them all, *A. Fordii* is by far the most important so far as production of tung oil is concerned. According to reports, however, *A. montana* supplies at least some of the oil produced in the warmer parts of China.

A. Fordii, a native of China, is a deciduous tree and grows 25 to 40 feet and more in height. The leaves are heart-shaped, though often with three more or less distinct lobes, large and dark green in color. The fruit is from two to three inches in diameter, olive green turning to a dark or deep brown when mature and dry. The fruit may be borne singly or in clusters of two or more, according to type, and is generally more or less spherical in shape. The common distinction of types as "single" and "cluster" designates how the fruit is borne, whether one fruit or two or more at the ends of twigs. The fruit, often referred to as a "nut," consists of an outer portion or husk and usually five seeds, sometimes three to seven of them. When mature the fruit falls to the ground and when dry is ready for harvest.

Development in the United States

Since the introduction of the tung tree there have been more than 150,000 acres planted to it in the United States, mostly in Mississippi, Louisiana, Florida, Alabama, Georgia and Texas. The 1940 census shows a total of 12,671,000 trees of all ages in the United States, and there have been heavy plantings since the year of that report.

The first tung seed brought into this country in 1905 were received by the United States Department of Agriculture from Consul General L. S. Wilcox at Hankow, China. These seed were planted in the Department's Plant Introduction Garden at Chico, California, and seedlings were distributed from there to various cooperators. Several times during subsequent years the Department received other seed from China; these, together with seed produced by the first trees grown here, were planted, and many small nursery trees were sent to various parts of the country for testing wherever climatic conditions seemed to offer possibilities for tung tree growth.

Several trees went to Tallahassee, Florida, and in 1906 Mr. William H. Raynes planted five on his plantation

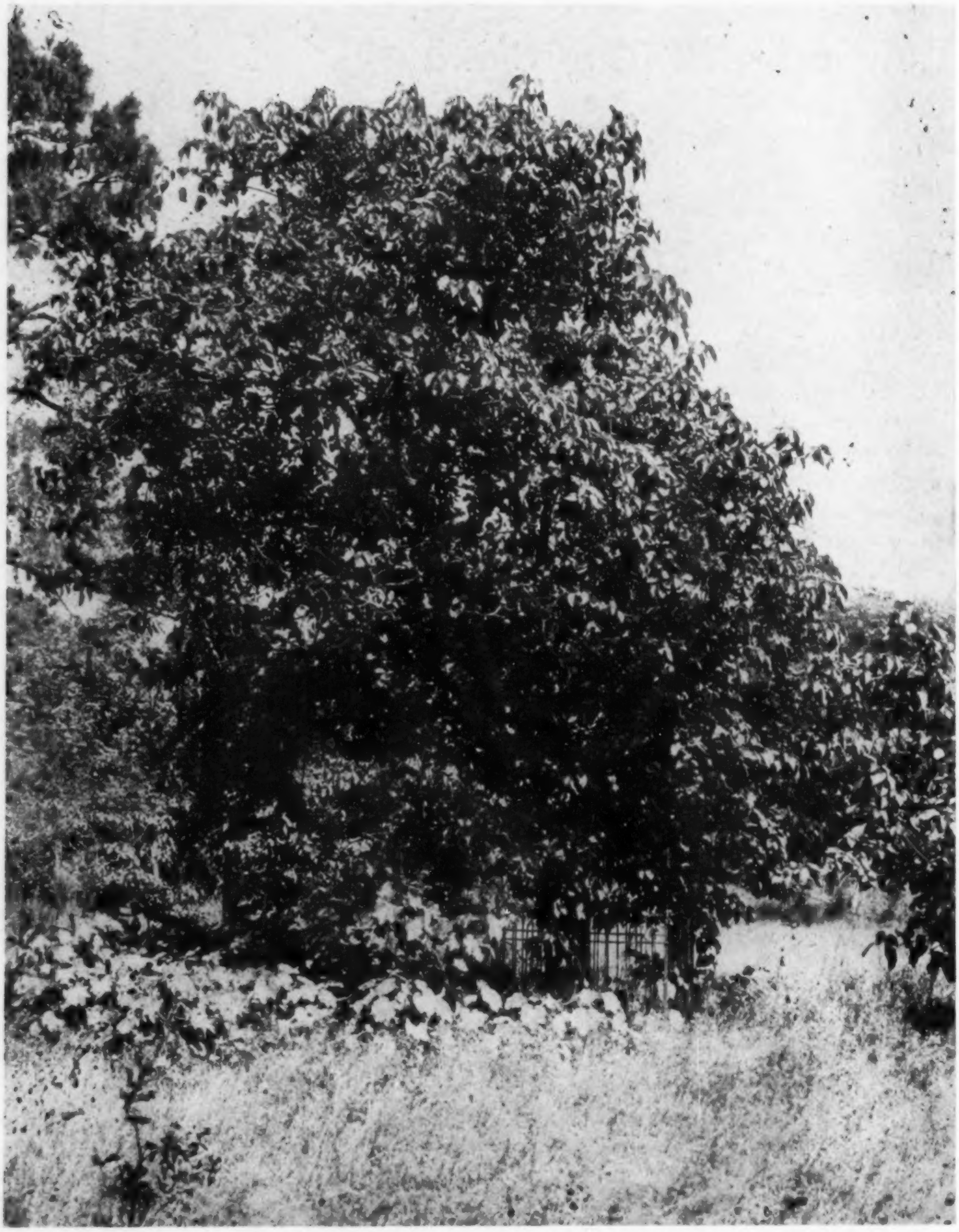

FIG. 1. In 1905 seeds of the tung tree (*Aleurites Fordii*) were first imported from China into the United States by the U. S. Department of Agriculture. Of the seedlings raised from these seeds at the Department's Plant Introduction Garden at Chico, Cal., five went to Mr. W. H. Raynes, on whose plantation near Tallahassee, Fla., they were planted. One of them survived, pictured here, and lived until August, 1940, when it died after removal for road construction.

nearby. One of them survived and lived until August, 1940, when it died after its removal from the right-of-way for a new highway. At the time the tree was removed and replanted it was about 35 feet tall and had a trunk circumference of 5.29 feet. The tree bore three fruits in 1908 and continued to yield each year except when spring frosts destroyed the blooms and during the time it was recovering from damage caused by a fire which destroyed the plantation home shortly after Mr. Raynes died in 1914. In 1913 the Educational Bureau of the Paint Manufacturers' Association expressed 2.2 gallons of oil from 1,095 fruits produced by the Raynes tree, this being the first American-grown tung oil. In 1913 Mr. Tennant Ronalds, near Tallahassee, planted four acres with seed of the Raynes tree and later increased the orchard to 40 acres.

One of the trees distributed by the U. S. Department of Agriculture from the early nursery at Chico, was planted by Mr. J. B. Wight at Cairo, Georgia. This tree is still living and has produced many crops of fruit. There are also several old tung trees in Baldwin County, Alabama, which were evidently planted during the early days of tung trials, as they are now of large size.

The Texas Experiment Station planted two trees in 1907 and two in 1908. It is reported that the first two and one of the second pair lived until January, 1930, when they were killed by a temperature of −4 degrees F.

Early tests of the tung tree at the Florida Agricultural Experiment Station began in 1912 when ten trees were received from the United States Department of Agriculture and planted in the Horticultural Grounds. Some of the original trees died and were replaced in 1914. Certain ones of the first planted trees began to bear in 1916. All these trees are still vigorous and in production, except No. 5, which was killed by the extreme cold of November 15–17, 1940, and No. 10, which was killed by mushroom root-rot in 1945. The average annual yield per tree of air-dried hulled seed from 1922 to 1946 inclusive varied from 5.6 to 65.7 pounds and the amount of oil calculated in the seed from 1.9 to 22.7 pounds. The average for all eight trees was 25.8 pounds of seed and 8.9 pounds of oil for the 25 years.

Soon after 1920, as a result of the ten trees growing on the Experiment Station Grounds, interest began to be manifested in tung culture, and a small orchard was planted near Gainesville, Florida, in 1923. In 1924–25 the American Paint and Varnish Manufacturers' Association planted an experimental orchard in another part of this area, but the land selected was too wet for tung trees and the test was not successful.

Tung Tree in China

The Chinese have been familiar with tung oil for centuries. However, they apparently have given little attention to the culture of the tree, since it could be planted in waste places, such as ditch banks and hillsides, and in due time would produce fruit. No large cultivated orchards have been reported, but apparently some small ones have been maintained.

The tree is said to thrive best in hilly regions where the altitude does not exceed 2,500 feet. This impression may be due to the fact that such hilly sections are the principal locations of plantings, as they more than likely are the waste lands which can not be utilized for more intensive agricultural production. This situation is quite different from that in the United States where trees have always thrived best on good soils and have never succeeded on those with low fertility or in the wild without cultivation.

It has been reported from China that the trees can withstand a temperature

FIG. 2 (*Upper*). A tung tree in full flower in early spring before the leaves appear. FIG. 3 (*Lower*). A tung orchard after the leaves have fallen and the fruits have been gathered in sacks.

of 4° F., but this doubtless refers to *A. Fordii,* as *A. montana* will not survive at such a low temperature in the United States and has been killed to the ground by a sudden fall in temperature to 18° or 20° F. This agrees with the experience in the United States with *A. Fordii,* except that temperatures of 26° and 28° F. have caused damage to trees of all ages when not thoroughly dormant.

The tree in China is said to attain a height of 10 to 30 feet, with a trunk diameter of six to ten inches, and begins to bear in three to six years and to decline in ten years. It is said that the trees pass their maximum producing capacity at about 10 years of age and are replaced by new plants in 12 to 14 years. Yields are said to be from 30 to 40 pounds of fruit per tree annually when at the height of production. These data, as reported for China, show less growth and yields than those obtained in the best producing areas in the United States where tung has been extensively planted.

Reports state that the Chinese farmer clears away a place in the waste land to plant the trees or seed, digs a hole and fills in with compost or some other type of good organic material, and the trees are allowed to grow until the strongest one can be determined; then the weaklings are removed. No additional fertilization and cultivation are given the soil except to cut the vegetation from around the trees to eliminate competition. This may account for the reported short life of the tung tree in China as compared with the prospective age of the tree in the United States where the best practice is to prepare the land before the trees are planted. There is probably some improvement taking place in China, or, at least, there are indications of this, as much of the information regarding cultural practices developed by the Florida Agricultural Experiment Station and other State and Federal agencies have been obtained by Chinese agricultural workers for the express purpose of testing these improved methods under conditions in China.

In China, harvesting the fruit, shelling, grinding the kernel and extracting the oil are quite different from the modern mechanical methods employed in the United States and certain other countries which have undertaken to establish a tung-oil industry. The Chinese practice is to allow the fruit to remain on the ground until the husks decay sufficiently to permit easy removal, when it is gathered and the seed removed. In some cases the fruit is gathered, placed in piles, and then covered with straw where it is allowed to remain and ferment, which accomplishes the desired purpose of getting the husks in such condition that they can be readily removed by hand. The husked seed are carried in baskets slung on poles to small mills where the oil is expressed by hand in a crude and unique type of wooden press.

The oil is purchased from the small mills by agents and transported in baskets by labor to collection stations or river points from which it is transported to the coasts. By a settling process much of the solid impurities are eliminated. The oil itself is then separated into different grades, with the lightest in color being the best.

When the oil-laden junks arrive at distribution points, the baskets are unloaded by labor where the oil is placed in tanks. Further settling takes place in these tanks and the oil is again separated into different grades, according to color and apparent purity. Formerly the oil was transported to America in oak barrels, but in later years tank steamers have been utilized for considerable quantities in bulk.

Reports indicate that there has been great reduction in adulteration of tung oil in China during the past decade or so. In 1929 the Chinese National Government put into effect an inspection

FIG. 4 (*Upper*). A tung tree in fruit. FIG. 5 (*Lower*). Tung trees planted on a contour with blue lupines as a cover crop.

service of tung oil for shipment to foreign destinations and established specifications based on foreign requirements.

Importance and Uses

Tung oil, being an important drying oil, is utilized in large quantities in a great many industries. For many centuries the Chinese have used the oil in various ways but most extensively in paints and waterproofing materials, as in other countries. Crude grades of it are used to coat the Chinese boat or junk instead of covering it with paint. The residue after the oil is expressed from the nuts is used to make a caulking ma-

terial for boats. This is accomplished by burning the residue to a soot which is then mixed with the oil to form a paste to make the caulking substance.

The Chinese also use the oil in its natural state as a protective covering for houses, furniture and other woodwork. Other uses include waterproofing material for masonry, cloth shoes, clothing, baskets and paper.

In America, tung oil is used in the manufacture of varnishes, enamel paint, floor paint, flat wall paint, paint driers, and to make waterproof or spar varnishes. It is also used in the manufacture of oilcloth and linoleum and for waterproofing cloth and many other articles. The electrical industry utilizes large quantities in making insulating compounds for cables, dynamos, motors and other such uses.

There has been an increasing demand for tung oil in America and other countries, but American industries of various kinds use more tung oil than those of any other one country. Extensive research has resulted in increased use.

Tung oil paints give a glossier finish than linseed oil paints, being much more like enamel in this respect. Therefore, they provide a smooth surface which can be easily cleaned. It is said that they are somewhat more resistant to fungus attacks than ordinary paints.

Tung oil was important in connection with many phases of the war program of the United States and her Allies. Consequently, when the United States became involved in war, steps were taken to conserve the supply of tung oil for war purposes, and to this end the Government had the full wholehearted cooperation of American growers and American industry.

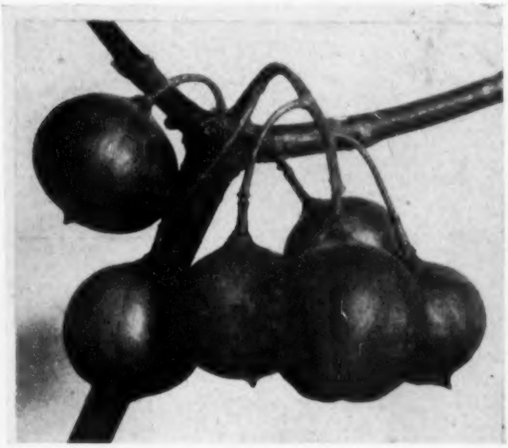
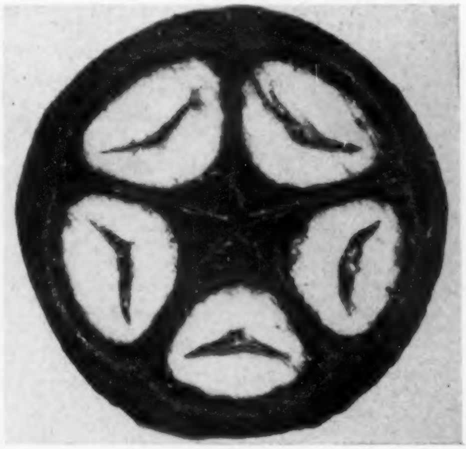

FIG. 6 (*Left*). Cluster-type of tung fruits. In the other known type the fruits are borne singly. FIG. 7 (*Right*). Cross-section of the fruit.

Sources of Tung Oil

The principal geographical source of tung oil has been China. Total annual imports into the United States, according to the Bureau of Foreign and Domestic Commerce, United States Department of Commerce, from 1925 to 1940, inclusive, varied from 83,004,000 to 174,885,000 pounds. From January 1 to September 30, 1941, 25,894,000 pounds were imported.

The existing situation regarding the supply of tung oil stocks for American manufacturing concerns has brought about an abnormal condition with reference to the price of the oil. Conse-

TABLE 1

TUNG OIL IMPORTATIONS INTO UNITED STATES[1]
(IN POUNDS)

1925—101,554,000	1933—118,762,000
1926— 83,004,000	1934—110,007,000
1927— 89,650,000	1935—120,059,000
1928—109,222,000	1936—134,830,000
1929—119,678,000	1937—174,885,000
1930—126,323,000	1938—107,456,000
1931— 79,311,000	1939— 78,718,000
1932— 75,922,000	1940— 97,049,000
1941—25,894,000[2]	

[1] From U. S. Dept. of Commerce, Bureau of Foreign and Domestic Commerce.
[2] January 1 to September 30.

quently, tung oil is now selling at a price much higher than that received before the war. From 1923 to 1929 the price of imported oil averaged about 12 cents per pound; after 1929 the price began to decline until it reached a low of about four cents per pound in 1933 and 1934. After this there was some increase which was only slight until about 1938 when the price was much higher than that received from 1923 to 1929.

Fruit grown in the United States now furnishes only a small part of the oil required by American manufacturers. However, the supply is gradually increasing, and the U.S.D.A. Crop Reports estimate the 1946 production in the United States at 47,300 tons of fruit which should have yielded approximately 15,136,000 pounds of oil. The estimated yield in 1946 is 28% greater than the 1945 production.

TABLE 2

TUNG FRUIT (NUTS) PRODUCTION IN UNITED STATES[1]

Year	Alabama		Florida		Georgia	
	Tons	Value	Tons	Value	Tons	Value
1939	20	$ 900	550	$ 22,000	15	$ 700
1940	200	13,000	4,700	282,000	1,200	77,000
1941	350	33,000	2,250	202,000	650	60,000
1942	500	47,000	3,700	333,000	950	89,000
1943	100	10,000	700	65,000	200	19,000
1944	700	70,000	7,000	700,000	800	75,000
1945	1,140	117,000	8,400	823,000	1,100	102,000
1946[3]	1,300	134,000	10,500	1,029,000	1,500	144,000

Year	Louisiana[2]		Mississippi		United States	
	Tons	Value	Tons	Value	Tons	Value
1939	150	$ 600	425	$ 1,900	1,160	$ 48,600
1940	1,200	66,000	3,700	222,000	11,000	660,000
1941	1,800	164,000	3,700	314,000	8,750	773,000
1942	4,000	384,000	7,200	684,000	16,350	1,501,000
1943	3,260	326,000	1,940	194,000	6,200	614,000
1944	7,550	778,000	10,630	1,106,000	26,680	2,729,000
1945	10,750	1,086,000	15,690	1,538,000	37,080	3,666,000
1946[3]	14,000	1,379,000	20,000	2,020,000	47,300	4,706,000

[1] U.S.D.A. Crop Reports.
[2] Includes some quantities from Texas.
[3] Preliminary.

Soils and Location

It is important that suitable soils be selected on which to locate the tung orchard. Trees have grown best on soils with a friable clay subsoil which may be classed generally as well drained sandy loams of the good farming lands of the South that are moderately acid in reaction. The soils must have good water drainage, and the site of the orchard be greater than where such is not the case. But within the best areas as to general elevations, there are some locations and pockets of low lands which have poor air drainage, and these dangerous spots should not be planted to tung trees. However, there is a direct correlation between the relative dormancy, growth and vigor of the trees and cold damage. In general it can be said that

FIG. 8. One type of orchard bin used for storing fruits loose.

should have adequate air drainage to avoid undue losses from freezing temperatures which may occur after the trees force into bloom.

The importance of the location of the tung orchard with reference to cold can not be over-emphasized. In certain areas where a mass of cold air is likely to flow in after periods of warm weather and force the trees into growth, losses will when tung trees are thoroughly dormant they can stand relatively low temperatures without injury, though there will be some variation between individual trees. Trees in active growth, or those just forcing into growth, are subject to losses during freezing temperature, especially in killing the bloom buds. Yet, tung trees require enough cold for an adequate dormant rest period, and for

this reason they do not succeed in the subtropical areas of the United States.

Planting

Tung orchards have been planted almost entirely with seedling stock, but budded and grafted trees are being tested. Large scale experiments with budding and grafting are being conducted by the U. S. Department of Agriculture, B. P. I., S. & A. E. Tung Investigations Laboratories, and these will supply much needed information as to the possibilities of improving production by asexual propagation. Tests show that prolific trees with the most stable characteristics will transmit such prolificness to a high percentage of seedlings grown from seed produced by such trees. Therefore, growers do not hesitate to plant large acreages with seedling trees grown from seed selected from vigorous and productive trees.

Fertilizers and Cover-Crops

Fertilization and maintenance of soil fertility are of great importance in connection with successful tung culture. Fertilizer experiments have shown that nitrogen and potash are very important in maintaining tung production. The percentages of these will vary under different conditions of soils and of the cover-crops grown and returned. During the first two or three years one-half to one pound for each year of attained age of the trees will generally take care of the requirements. The mixture should contain approximately 8% nitrogen and 8% potash. Most growers, however, apply some phosphoric acid either in the fertilizer mixture or to the land for the satisfactory growth of some good leguminous cover-crop. After trees reach bearing age, they will generally require more potash on most soils, which can be provided by additional applications. When

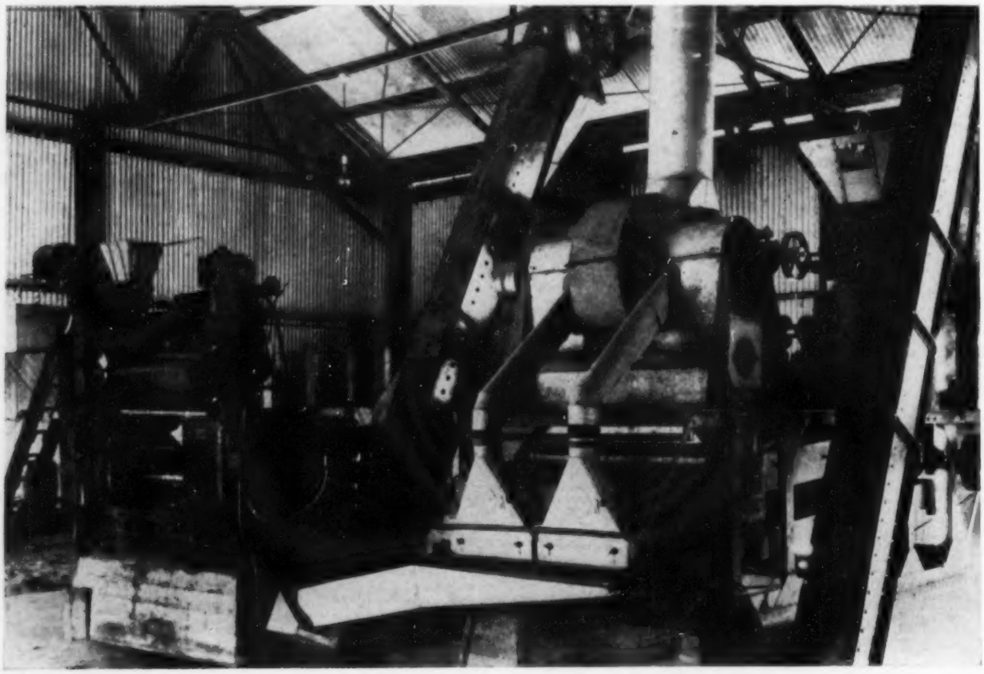

FIG. 9. Tung oil-expressing machinery, press at left and decorticator at right. (*Courtesy of the Alachua Tung Oil Co.*).

phosphoric acid is applied in the tree fertilizer, the mixture usually contains about 8%, derived from either superphosphate or basic slag. Fertilizers are applied at the rate of about one pound for each year of attained age of the tree. In soils of low fertility the amount of fertilizer should be increased to about two pounds per year of tree age. Trees receiving too little potash will develop a potassium deficiency, and when such deficiency is severe, it will cause early defoliation and result in greatly reduced yields and death of the trees. Regardless of the commercial fertilizer used, growers make a practice of applying the tung hulls and tung cake meal in the orchard, when it is possible for it to be returned from the mill.

In addition to the regular fertilizers containing nitrogen, phosphoric acid and potash, tung trees in many areas require an application of one or more supplements for best growth and production. The lack of certain elements in the soil in which tung trees are growing produces various disorders which are manifested by definite symptoms characteristic of the particular condition brought about by a deficiency of those elements.

The most important of the deficiencies in many parts is that of zinc, characterized by malformation and bronzing of the leaves, shortening of the internodes and development of a rosette, as growth progresses. This physiological disorder made its appearance in tung trees soon after some of the first commercial plantings were made, and it was commonly called "bronzing", due to the color of the leaves. Bronzing causes a weakened condition of the trees, and in cold weather severely affected trees may be killed to the ground. The trouble is corrected by application of zinc sulfate to the soil or to the leaves as a spray. Bronzing threatened to retard seriously the development of the tung oil industry when it first made its appearance but research at the Florida Agricultural Experiment Station determined the cause and evolved methods of control.

Manganese and iron deficiencies have also been identified through research at the Florida Station. Manganese deficiency presents as its most typical symptom a chlorosis in the leaves which has been designated "frenching." It can be corrected with manganese sulfate applied either to the soil or to the tree in a foliage spray. Iron deficiency has been noted only in limited localized areas in a few orchards. It has been rather confined to definite sections in the affected orchards where groups of trees showed the typical chlorosis in the leaves. When severe, the affected trees make poor growth and produce light crops of fruit. Iron deficiency is corrected with iron sulfate applied to the soil in which the affected trees are growing, or sprayed on the leaves.

The Florida Agricultural Experiment Station and the United States Department of Agriculture, B. P. I., S. & A. E., cooperating, have identified two other deficiencies and worked out control measures. One of these is caused by too little copper available in the soil and the other is due to a lack of magnesium. Growth and production are greatly retarded when trees are severely affected.

Severe copper deficiency has been observed in some orchards in the Gainesville and Williston, Florida, areas. The disorder can be identified by a reduction in the size of the leaves, later by defoliation, and in advanced stages by a dying back of the terminal twigs. The development of the cupped shape of the leaves has suggested the name "cupping", by which the deficiency is commonly known. This disorder is corrected by applications of copper sulfate to the soil or in a solution sprayed on the foliage.

Magnesium deficiency has been quite prevalent in certain areas where tung trees are being grown on some of the

sandier soils and, when severe, it affects growth and production. It is characterized by marginal leaf scorch, and in some instances the necrotic areas in the leaf progress inward between the veins, closely resembling symptoms of potassium deficiency. The visible symptoms usually are not evident until July or later. Premature defoliation takes place in late summer on trees severely affected. This deficiency is controlled by applications of magnesium to the soil, and since the sulfate is soluble, it is used for quick results.

Tung trees respond to organic material supplied to the soil, and therefore it is advisable to grow and return cover-crops to the land for best results in maintaining tung production. There are several green manure crops which can be utilized for this purpose, but legumes are best, since they fix and return atmospheric nitrogen to the soil in addition to organic matter produced.

During the first several years after starting the orchard the main area cultivated throughout the summer is a strip the width of a disk harrow on each side of the tree rows. This permits the growing of some satisfactory summer legume, such as *Crotalaria,* Alyce clover and beggarweed.

Winter cover-crops of lupines, vetches and peas are important in tung culture, and they can be grown satisfactorily on lands which have a considerable amount of clay. Soils with little clay and those of a deep sandy nature are generally not adapted for successful growth of these winter legumes, although under some conditions with late planting and heavy fertilization fairly good results can be obtained with some of these crops. These winter legumes give excellent results in the program for the maintenance of soil fertility, since they grow at a time when the trees are dormant and there is no competition with them for the moisture in the soil.

Insects and Diseases

At present there are no insect and fungus diseases of tung trees causing universal losses. There are a few which have made their appearance, but they have not caused serious reductions in production except in localized areas.

Nematodes have caused some trouble on nursery stock when the trees were planted on lands heavily infested with them. However, experimental plantings of heavily infested nursery stock on the Florida Experiment Station Farm grew out of the infestation and, when removed a few years later, were free of root-knot and made satisfactory growth. Therefore, nematodes may cause severe damage to young trees in the nursery and seriously retard their growth during the first year or two, but when the trees are transplanted to the orchard the root-knot disappears.

There have been three scale insects reported on tung trees, none of which has proved serious to date. They are the ivy scale (*Aspidiotus hederae* (Vall.)), latania scale (*Aspidiotus lataniae* (Siga)) and the cottony cushion scale (*Icerya purchasi* (Mase)). If necessary, the first two can be controlled with a dormant spray of lime sulfur or oil. The cottony cushion scale can be controlled biologically with *Vedalia* lady-bird beetle released in the orchard when infestations are sufficiently severe to warrant control measures.

Thread blight (*Corticium Stevensii* (Burt)) has produced severe injury in parts of some orchards, and when severe, causes a dying back of the branches. It can be controlled by spraying with Bordeaux mixture. One bacterial spot (*Bacterium aleuritidis* (McCulloch and Demaree)) of tung leaves has been described, but no serious damage caused by it has been reported.

Mushroom root-rot (*Clitocybe tabescens* (Scop.) (Bres.)) disease has killed tung trees in localized areas in some

orchards. It generally occurs only where oaks and other native host trees have been cleared away to permit planting tung trees.

Harvesting

The methods employed in harvesting the fruit are quite simple. When the fruit becomes fully mature in autumn, it drops from the trees and is generally allowed to remain on the ground until dry, but if drying equipment is available, moist fruit can be gathered. It is picked up by hand and either sacked and placed in covered sheds to dry further or run through dryers and then placed loose in well ventilated buildings erected especially for the purpose. When stored in sacks the sacks are stacked in such a manner that air has free passage between them.

The buildings in which fruit is stored loose in the orchard are so constructed that air has free access from the center outward. This is generally accomplished by erecting a crib-like structure, with poultry netting nailed to the framework so as to leave the sides open for ventilation. Holes covered with wire netting are left in the floor to insure ventilation and also for ease in removing the fruit. These large outdoor bins are built at convenient locations in the orchard where the fruit can be placed in them as it is gathered. Unloading is accomplished with a gasoline engine-powered portable elevator which conveys the fruit from the building into the truck body. Some storage buildings at the mill have forced ventilation, and most of them are equipped with conveyors for transporting fruit to the processing machinery.

Where the fruit is stored in sacks the buildings are generally long open sheds of easy access with the roof about six to eight feet high to allow convenient stacking. The sacks, tied in the orchard, are allowed to remain in these sheds until the time of milling the fruit, when they are loaded onto trucks and transported to processing plants. At the mills the fruit is dumped into large bins convenient to the conveyor belts running to the presses, and the empty sacks returned to the grower.

Care must be exercised to prevent too high a moisture content of the fruit at the time of milling. This is the reason the fruit is allowed to become as dry as possible before it is picked from the ground. It also explains why it is necessary to store the fruit in well ventilated, dry places which, in addition, insure further drying out of any excess moisture. The fruit should not contain too much moisture when it is to be shelled and run through the presses, for when too moist (more than 10% to 12% moisture) the seed gives trouble in the presses, and it is impossible to recover the oil in as high percentage as when the fruit is properly dried. However, many mills are now equipped with dryers with which fruit can be dried to where it will have the optimum moisture content.

The first mill to be built in America, and in the world, for complete modern mechanical expressing of oil from tung seed, was erected in 1928 by the Alachua Tung Oil Company on their property near Gainesville, Florida. This plant initiated commercial production of tung oil in the United States, and the first tank car of American tung oil was shipped from Gainesville, Florida, in 1930, 17 years after the first oil was expressed from American grown tung fruit produced at Tallahassee, Florida. In addition to the mill at Gainesville, there are two others in Florida located at Brooker and Lamont. There are mills also in Georgia, Alabama, Mississippi and Louisiana, at strategical locations which, in connection with the Florida plants, can process the present production of tung fruit in the United States.

These plants contain modern equipment for decorticating the fruit, grinding

the kernels and expressing the oil from the kernels. The decorticator, which is the machine that removes the hull or husk from the seed, consists of a rotary disk and huller. The seeds are delivered from these machines, after decortication, into conveyors in which they are transported to grinders and then to the presses. There the seed-meal passes through the press, generally a screw type, where the oil is expressed under pressure. The oil is then passed through filters for removal of solid matter and for clarifying, and it is then ready to be placed in storage tanks or tank cars for shipment. An average of about 16% (slightly higher in some fruit) of oil on the basis of the weight of the air-dried whole fruit is obtained by the expeller type presses. Thus the average amount of oil recovered is generally calculated to be about 320 to 350 pounds of oil per ton of whole fruit. The fruit, other than that produced by the mill owners, is either purchased from the growers or processed at a designated price per ton.

American produced tung oil is of very high and satisfactory quality. The oil is light golden or light amber in color and is nearly transparent after it has passed through the filters.

The tung cake, which is the residue left after the oil has been expelled, contains various percentages of oil, sometimes as much as 5%, which would be worth several dollars per ton of fruit at present prices if the oil could be recovered. This problem is being investigated in an effort to develop improved methods of expelling or extraction, together with the possibility of extracting the oil from the cake with solvents.

Varieties

Up to the present there has not been any great attempt to introduce named tung varieties. Tree No. 2 of the original ten trees on the Florida Experiment Station grounds has come to be known generally as the "Florida." This is a cluster type and has been the source, directly or indirectly, of considerable acreage in tung in the United States.

Tree No. 9 has been utilized in many plantings and has been so designated, and, while it has not been given a name, it can be considered as a variety and may be given an acceptable name at some future date. It has certainly had an excellent record in point of production and has the ability of passing on to its progeny the vigor and prolificness that make it stand out prominently among tung varieties.

Workers in the United States Department of Agriculture in tung investigations have selected a large number of clones with which they are conducting experiments. These have been chosen as foundation stock with which to carry on their breeding and propagation work.

The tung industry is still in the seedling stage, and it will continue so until methods of asexual propagation are in general use. Especially is this true in face of the fact that it is possible to make selections of certain individual trees which will pass on their prolific characteristics to a large percentage of their progeny.

The tung industry to date has been developed and expanded rather rapidly over a wide area in the South. The pioneer spirit of the American people has again been emphasized, for those who have made these early tung plantings are truly pioneers, just as others have been who paved the way for many other horticultural industries in the United States.

Research

A great amount of research is being carried by the various State Experiment Stations and the United States Department of Agriculture in the commercial tung-producing area of the South. The Florida Agricultural Experiment Station has been active in this field since

1912. The United States Department of Agriculture began testing tung trees in 1905. In 1938 the Bureau of Plant Industry (now B. P. I., S. & A. E.) set up Laboratories for Tung Investigations at the Florida Agricultural Experiment Station, Gainesville, Florida; at Cairo, Georgia; at the Alabama Gulf Sub-Station, Fairhope, Alabama; and at Bogalusa, Louisiana. In the same year laboratories were opened at Gainesville, Florida, and Bogalusa, Louisiana, by the Bureau of Agricultural Chemistry and Engineering.

Utilization Abstracts

Tonka Beans. From 1941 through 1945 Brazil shipped to the United States an annual average of $47,000 worth of tonka beans, the seeds of *Dipteryx odorata*. This tree flourishes in the Brazilian states of Amazonas, Pará and Mato Grasso, sometimes attaining a height of 100 feet. The fruit is a pod, about two inches long, mahogany in color when ripe, and contains a single shiny black seed. This seed or bean is known in Brazil as cumarú and is one source of an ingredient known as coumarin which is extensively used as a flavoring agent in the preparation of tobacco, snuff, cosmetics, soaps, perfumes and foodstuffs. It accounts in part for the pleasant fragrance of cigarettes, the delicate scent of toilet soaps and the piquant taste of liqueurs.

Fallen pods are gathered from January to March, the hard outer shells removed and the beans then spread out for two or three days to dry. They are next bagged and shipped in boats or canoes to nearby towns where they are soaked in native rum up to several days. When the rum is drained off the beans are again dried, and this process coats them with a white crystalline deposit of coumarin. They are then ready for export.

For use in cigarette tobacco, the most important use in the United States, the beans are ground and given another rum treatment, this time for about three months. The resulting liquid, rich in coumarin and highly aromatic, is drained off and sprayed over the tobacco, giving it a distinctive fragrance. The extract is used also in cakes, candies, preserves and liqueurs, as well as a substitute for vanilla. It has also been found to be a fixing agent in the manufacture of coloring materials. And medically the bean kernels have value in the treatment of general weakness and nausea. (*Anon., Brazilian Bulletin, Brazilian Gov't Trade Bureau 3(58): 1. 1946*).

2,4-D, a Selective Herbicide in the Tropics. The selective nature of 2,4-dichlorophenoxyacetic acid as a herbicide has found great use in controlling the weeds of sugar plantations in Puerto Rico, and promises to be of similar value in coffee plantations. These two economically important crop plants are unaffected by sprays of the herbicide in concentrations up to 0.3%, whereas many of the weeds interfering with these crops succumb to that or lower concentrations. Some non-graminaceous weeds are immune. This valuable application of a plant hormone has emerged from work at the institute of Tropical Agriculture at Mayaguez, Puerto Rico. The cost of weeding in sugar-cane plantations there has been reduced to 50¢ per acre, so far as chemicals are concerned, by this means, and some of the most serious weeds have been effectively controlled. *J. van Overbeek and Ismael Vélez, Science 103: 472. April 19, 1946*).

Lycopodium Powder. The inflammable, infinitely fine and almost impalpable spores of lycopodium found use during the recent war in connection with tracer bullets and flares. In peace-time they were used for dusting pattern molds, for packing pills, and, since they crackle brilliantly when they burn, as an ingredient in fireworks. Prior to 1942 the chief source of the powder was Japan which supplied 47,698 pounds in the period 1939–1941. (*Anon., Herbarist No. 12 p. 50. 1946*).

Chemical Control of Plant Growth[1]

The latest applications of physiologic principles to the solution of agricultural and horticultural problems involve the use of synthetic hormones to stimulate rooting of cuttings, to effect blossom thinning in fruit production, to prevent pre-harvest fruit drop, to produce seedless fruit, to achieve control of weeds, to break as well as to prolong dormancy, and to bring about other economically important controls of plant growth.

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AND

BETTY F. THOMSON
Connecticut College

Introduction

A CHEMICAL revolution is sweeping through the agricultural world. It is unrivalled by any of the previous great advances in agriculture, and perhaps by most advances in the biological field. For the first time, man can change the pattern of growth and development of plants, can retard growth here or speed it there. The growth-controlling hormones and other chemicals now in use are but the crude beginnings.

The present chemical advance in no way lessens the importance of the great developments of the past. Mechanical inventions, such as the steel plow, the drill, the combine-harvester and the cotton picker, were great forward steps in agricultural progress. Even now, agricultural machine development is far from over, and the applications of new machines to problems of production will continue to be important. In agriculture as in industry, mass production—the cultivation of extensive acreage with only a few men—is one of the important consequences of the machine.

Abundance of crops has always been a necessity for the well-being of any nation with an agricultural economy. Once the virgin fertility of agricultural soils approached exhaustion, the matter of artificial fertilizers demanded attention. This was a biological and chemical problem in the control of plant growth. It was discovered long ago that certain elements are essential for the growth of all plants (nitrogen, phosphorus, potassium, calcium, *etc.*), and that some soils are deficient in one or more of these. It was also found that traces of certain other elements (manganese, boron, zinc, *etc.*) are required for the satisfactory growth of many kinds of plants. Such discoveries were the very foundation of the fertilizer industry and have gone far toward making possible the economic production of crops in areas that might otherwise constitute marginal land.

Another great advance in agriculture has been in the field of plant breeding, in which new varieties and strains of plants have been produced which are

[1] This report is a brief résumé of a book soon to be published under the title "Hormones and Horticulture" by the McGraw-Hill Book Company, Inc. Other authors of the book are Elizabeth Bindloss Johnson and Ruth M. Addoms.

high-yielding, disease-resistant, and in many other ways improved for the use of man. Hybridization of corn is an outstanding example wherein the advantages of "hybrid vigor" were made available to the average agriculturist.

The present great advance we interpret as a real chemical revolution in agricultural practice. The application of chemistry to soil fertilization and the protection of crops against the ravages of insect and fungus pests was highly important, though hardly revolutionary. But with the current efforts to regulate growth by the application of minute amounts of synthetic growth-controlling hormones, we enter an important new era.

A little about the background of theoretical research which led to current developments: Twenty years ago a young student at the University of Utrecht, in Holland, was working with his famous father on a theoretical problem in plant physiology. His name was Frits Went, and his father, the late F. A. F. C. Went, was Professor of Botany at Utrecht. One of Went's goals was to find an explanation for the response of plants to light and to gravity. That the above ground parts of plants grow upward away from gravity, and toward light when it comes from one side, had been observed for centuries. Darwin had suggested in 1880 that a chemical substance was involved in the response, and Boysen Jensen showed in 1910 that a chemical substance was indeed involved, a substance which under certain conditions stimulated growth. Numerous researchers contributed other important information, and by the middle 1920's the stage was set for Went's work. His important contribution proved to be a method for detecting the presence of growth-controlling hormones and measuring them. Once such an assay method was available, it was possible to determine the chemical nature of plant hormones, the extent of their occurrence in living organisms, and, most important of all, something of their relation to growth. The time was then ripe for an advance in man's understanding of the regulation of plant growth by hormones.

It is interesting to note that a major share of the fundamental research on plant hormones has been carried out with seedling plants of oats. Indeed, Went's quantitative assay method (published in 1928) is based on the degree of response of oat seedlings to the hormone to be tested.

It is a long but highly significant advance from the theoretical researches on oats to applied problems such as control of flowering, of preharvest drop of fruit and the killing of weeds. This advance would hardly have been possible without the chemical work of Kögl, Haagen-Smit and Erxleben. In 1934 these workers found that indoleacetic acid was very active as a plant hormone. The compound had originally been isolated in 1885 from normal and pathological urines, and first prepared synthetically in 1925. But it remained for Kögl *et al.* to establish its identity as a plant hormone. Indoleacetic acid was never used for practical growth control problems; it was too difficult and expensive to make. Less expensive compounds were in the offing.

Hormones and the Rooting of Cuttings

The discovery in 1935 of several new synthetic hormones by Zimmerman and Wilcoxon, and the success of these compounds in speeding the rooting of cuttings, has made possible significant new techniques in plant propagation. Several commercial preparations are now available and appear under the trade names Hormodin (Merck & Co.), Quick-Root (Dow Chemical Co.), Rootone (American Chemical Paint Co.) and

StimRoot (Plant Products Co.). Chemically speaking, the synthetic hormones in these root-inducing compounds are known as naphthaleneacetic and indolebutyric acids (those discovered by Zimmerman and Wilcoxon). The hormones are mixed in minute amounts with talc and sold in powder form; plant cuttings to be rooted are merely dipped in the powder before being placed in the moist sand rooting medium.

FIG. 1 (*Upper*). Rooting of holly cuttings hastened by hormone treatment. Left, not treated; right, treated with hormone powder; both pictured after 45 days in rooting medium. (*Courtesy Boyce Thompson Institute for Plant Research.*)

FIG. 2 (*Lower*). Spring bud-growth in pecan hastened by hormone treatment after a mild winter. Left, twig from unsprayed tree; right, twig from tree sprayed four times with a dinitrophenol preparation. Pictures taken on same day. Sprayed trees leafed-out about two weeks earlier than the unsprayed. (*Courtesy C. W. Van Horn, Arizona.*)

The greatest contribution of hormones to plant propagation lies in their success in bringing about earlier rooting and sturdier root systems in the cuttings of a great many species of deciduous flowering shrubs and broadleaf evergreens. Hormone treatment also increases the percentage of rooting in difficult-to-root cuttings. (Fig. 1.)

In some species, rooting has not been markedly improved by hormone treatment; and hormones are of no advantage, as yet, in the rooting of cuttings of plants which are never known to root without them. But in plants which are slow or otherwise difficult to root, or give sparse rooting, hormones have been such an advantage that nurserymen as well as amateur gardeners now use them widely.

Blossom Thinning Sprays in the Control of Fruit Production in Apple

Most apple varieties (*e.g.*, Wealthy) which are heavy bearers produce their crops in alternate years, thus necessitating a laborious and expensive hand-thinning operation in the year of bearing. Within the past few years chemical sprays have been discovered which will reduce fruit set by killing some of the flowers; this accomplishes both fruit thinning and more even yearly bearing, and at minimum expense. The work is still in the experimental stage but promises to make an important contribution to control of crop production. Cherries, peaches and other fruits, as well as apples, are now the object of investigation with blossom-thinning sprays.

The first tests to determine whether apples could be thinned by spraying the buds or flowers, without at the same time causing excessive leaf and fruit spur injury, were reported by Auchter and Roberts in 1935. Sprays of inorganic compounds were not effective, but cresylic acid and a tar oil distillate showed promise. Since that time a number of different compounds have been tested, and at present Elgetol (sodium 2,4-dintro-*o*-cresylate, of Standard Agricultural Chemicals, Inc.), and DN Dry Mix Nos. 1 and 2 (40% 2,4-dinitro-*o*-cyclohexyl phenol and 40% 2,4-dinitro-

o-cresol, respectively, of the Dow Chemical Co.) are most widely used in experimental work. The synthetic plant hormone, naphthaleneacetic acid, also promises to be effective in blossom thinning.

Present experiments indicate that thinning is most successful when sprays are applied to trees in full bloom. At this stage the center flower in each cluster has been pollinated and fruit development initiated. The remaining flowers in the cluster, those in full bloom when sprayed, fail to set fruit. Such treatment results in about 20% of the flowers setting fruit. In the apple variety Wealthy, only 5% of the flowers must develop into fruits to produce a full commercial crop. This means 20 to 25 fruits per 100 blossoming spurs, after the June drop.

The most striking use of thinning sprays is in the control of biennial bearing. Heavy bearing varieties, such as Wealthy, Yellow Transparent and Golden Delicious, if adequately thinned in the "on" year give a full commercial crop in the succeeding "off" year.

The major benefits reported from the use of thinning sprays on apples are decreased orchard costs and greater income from fruit as a result of control of biennial bearing; other advantages are increased yield of fruit, improvement in the color of the red varieties, and better pest control.

Thus far, standard treatments have not been established for most commercial varieties of apple; Wealthy is the outstanding exception. However, the basic experimental work is well in hand, and only trials by the average grower can determine the usefulness of this new horticultural tool.

Control of Preharvest Drop of Fruits with Hormone Sprays

Crop losses as a result of premature drop—before the fruit ripens—may be quite serious for a number of fruits, for example, apples, pears, apricots, plums, peaches and oranges. The preharvest drop of apples may be as great as one-fourth to one-half the entire crop, and the drop may occur before the fruit has matured or developed good color. Under such conditions the grower must either risk a heavy fall of fruit or pick before the best quality and color are attained. (Fig. 3, 4.)

The fall of fruit and leaves is brought about by the separation of a special group of cells, the abscission layer, which is located where the fruits or leaves are attached to the stem.

That abscission could be delayed by spraying with synthetic plant hormones was first reported in 1939. Hormone treatment (dusts or sprays) is now used successfully and on a large scale in preventing preharvest drop of apples and pears, and fruit can be kept on the trees until mature. Thus far the treatment has not been extended to other fruits with complete success, but holly and a few other ornamental evergreens can be successfully treated to delay falling of leaves and berries for 10 to 14 days after cutting.

Numerous commercial hormone preparations for control of preharvest drop of apples are now obtainable: Applelok (Westville Laboratory), App-L-Set (Dow Chemical Co.), Fruitone (American Chemical Paint Co.), Hormex (Jean McLean Chemical Co.), Niagara-Stik (Niagara Sprayer and Chemical Co.), Parmone (E. I. du Pont de Nemours & Co.), Stafast (General Chemical Co.) and Stop Drop (Sherwin Williams Co.) are some of the compounds available. Most of these contain the potassium salt of naphthaleneacetic acid and are effective on such common varieties as McIntosh, Duchess and Delicious. Naphthaleneacetic acid is not so effective as 2,4-dichlorophenoxyacetic acid for control of preharvest drop in the

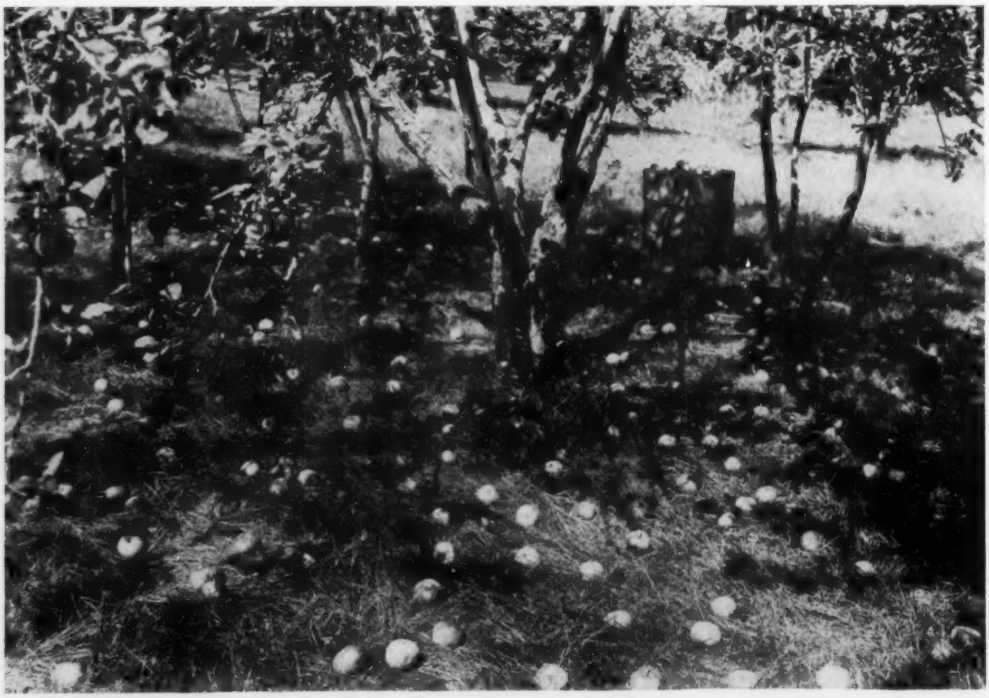

FIG. 3 (*Upper*). Pre-harvest drop of apples from unsprayed tree.

FIG. 4 (*Lower*). Absence of pre-harvest drop of apples from tree which received hormone spray. (*Courtesy Mass. Agr. Exp. Sta.*)

Winesap. Much experimental work remains to be done, both as to varieties and as to kinds of compounds. Dusts are easier and less expensive to apply, and fully as effective as sprays.

For large-scale application of hormones, airplane spraying is proving to be satisfactory. (Fig. 5.)

To be effective, the hormone must be applied before the dropping is well underway. Fruit should not be left on the tree so long after spraying that it becomes over-ripe, nor should the amount of hormone used be so great that fruit is "stuck" so tightly that the next year's fruiting spurs are injured during picking.

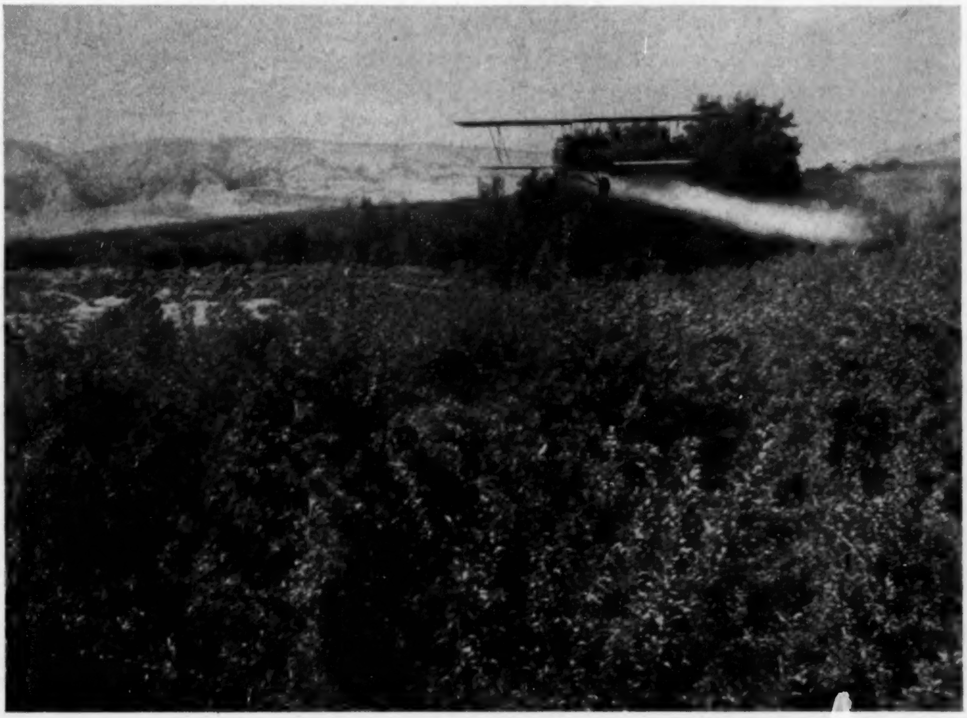

FIG. 5. Airplane application of hormone spray to apple orchard, two minutes per acre. (*Courtesy Central Aircraft, Inc., Yakima, Wash.*)

Hormones as Aids to Fruit Set and to Seedless Fruit Production

Pollination of the flower is essential to the formation of fruits of most kinds of plants. Occasionally, however, fruits develop normally without pollination and may then be seedless. Since pollination is dependent upon insects, wind and other climatic conditions, and even upon manual operations in some plants, it is highly desirable to possess a means for achieving the effects of pollination and subsequent fruit-set simply, and at will. This has been accomplished for several kinds of plants by the use of hormones.

Hormone-induced fruit-set is particularly important in improving the production of such greenhouse crops as tomatoes, where inadequate pollination in the winter season often results in light yield of fruit. Besides assuring fruit set, hormone treatment if correctly timed will result in seedless fruit.

Relatively few fruits are naturally seedless (*e.g.*, banana, navel orange,

seedless pear and grapefruit, grapes, Chinese persimmon), but hormone treatment may make possible many new kinds of artificially induced seedless fruits. Experimental work has only begun.

The first record in scientific literature of the use of specific hormones to produce mature seedless fruit is that of Gustafson in 1936. Howlett later suggested the use of chemicals to supplement the normal processes of pollination and fertilization in greenhouse tomato production.

To date, naphthaleneacetic acid has been the most widely used synthetic hormone for inducing seedless fruit, but Howlett recommends a mixture of indolebutyric and naphthoxyacetic acids, which has been widely tested by commercial greenhouses in Ohio the past two or three seasons. Thus far, application of hormones in water or emulsion sprays, or in aerosols, has proved best. The commercial preparations now available are Seed-less-Set (Plant Products Co.) and Fix (Thompson Horticultural Chemical Corp.); full directions for use accompany the products.

The time for application depends in part upon the effect desired; for seedless fruit in tomato, for example, the hormone should be applied before there is any danger of pollination (up to the time the flowers are completely open); for insuring fruit set in the greenhouse without special attention to seedlessness, the spray should be applied after the first flower of a cluster opens; second and third sprayings should be made at intervals of a few days during the blooming of the cluster. Spraying when several blossoms of a cluster are open gives more uniform sized fruits.

While the only real success has been with tomato, other fruits have been made seedless, and fruit set has been improved. In holly, a species where two plants of opposite sex are ordinarily necessary in order to obtain a set of fruit, berries may be produced by applying hormone sprays to the female flowers.

The main advances in seedless fruit production will come when the pomaceous fruits, berries, cherries and plums, can be made seedless by hormone sprays on a large scale. Before certain fruits will be improved, however, it will be necessary to dispense with the seed coats; in "seedless" watermelons, for example, the remaining empty "shell" of the seed is often as large as the normal seed. Seedless cherries and plums will be of no advantage unless some way is also found to prevent the "pit" from forming.

The extent to which hormones will be used commercially for assuring fruit set, or for seedless fruit production, will doubtless depend upon the discovery of new methods (and perhaps even new hormones) that will assure the results desired. Ultimately the increased value of the crop would have to be such that the added expense is worthwhile.

Hormone Treatment of Seeds

The idea of treating seeds with growth hormones of various kinds followed in the wake of their successful use in the rooting of cuttings. The procedure has been to apply hormones to dormant seeds, generally as a dust.

The objectives have been as follows: 1) to increase percentage of germination; 2) to increase rate of germination, especially of those seeds in which germination is normally delayed; 3) to counteract deleterious effects of fungicides; 4) to accelerate the growth rate of the plant and hence advance the date of maturity; 5) to increase yield, whether of a root, foliage or fruit crop.

To date, in spite of the excellent objectives, the results of seed treatment with hormones are largely negative; the German workers, Amlong and Naun-

dorf, are the only ones reporting widespread success. There are scattered cases where a mixture of hormone and thiourea increased the percentage of germination.

The most promising use of hormone treatment of seeds, thus far, is in combination with fungicides; such treatments are based on the theory that certain fungicides may suppress germination by inactivating the naturally occurring hormones in seeds. Even this work remains to be demonstrated beyond question. The most dramatic objective of seed treatment, that of increasing the entire subsequent growth and yield of plants by applying hormones to the seeds before planting, has not yet been realized. It appears that the natural supply of hormones (and/or vitamins) in seeds is adequate for germination and growth, and added amounts are of little or no advantage.

Not only is there scant evidence that hormones stimulate seed germination and subsequent growth, but there is abundant evidence that the synthetic hormone, 2,4-dichlorophenoxyacetic acid (2-4-D), will destroy many kinds of seeds, even when present in only minute amounts. Indeed, sterilization of soil on a field scale by treatment with small amounts of 2-4-D is one of the most promising new methods for weed control.

Hormones and Miscellaneous Growth Phenomena

Control of time of flowering. This objective, if widely realized, would probably do more to control the time of picking and marketing certain crops than anything we now know about. It was first shown in 1942 that spraying strawberries with the synthetic hormone naphthaleneacetic acid would retard flowering by three weeks, thus extending the picking and marketing season. And from Puerto Rico comes the report of van Overbeek that fruiting can be completely controlled in the Cabezona variety of pineapple. This variety ordinarily flowers sparsely, the entire flowering and fruiting period sometimes extending over a period as long as five years. However, a simple treatment of the growing tip of the plant with naphthaleneacetic acid or 2-4-D in minute amounts (0.005 to 0.01 per cent, in any month in the year) will bring plants into flower in about two months; mature fruits may be harvested about five months later. Thus the harvest period of Cabezona pineapple may be fully controlled. What was a disadvantage with an otherwise good quality variety was turned to an advantage with hormone treatment.

Ripening of fruit. Mitchell and Marth have reported that bananas, apples and pears, if picked while green, may be ripened by dipping in dilute solutions of 2-4-D; fruit so treated will ripen five to eight days ahead of the untreated fruit. Tomato did not respond to the treatment.

Hormones and transplanting. Transplanting trees, shrubs, and even herbaceous plants, often results in serious wilting and slow recovery, or occasionally in failure to survive at all. Because hormones are known to promote the rooting of cuttings, the idea has developed that they may also hasten the growth of new roots on transplanted plants. If so, they would stimulate resumption of normal growth rates and increase the numbers of individual plants which survive transplanting. Experiments along these lines have thus far disclosed no real advantage from hormone treatment. The best that can now be said is that, although there have been a few cases of quicker recovery after transplanting, no permanent improvement in growth results.

Weed Control by Hormone Preparations

One of the greatest single problems of agriculture is that of weed control.

Despite the fact that weed-killing chemicals have been known for many years, they have been relatively little used. Mechanical cultivation, arduous and costly, remains today the chief method of weed control. However, the situation is changing rapidly since the discovery that one of the synthetic hormones (2-4-D) will destroy some plants and leave at least a few others relatively unharmed. For the first time there is promise of revolutionary changes in the whole field of chemical control of weeds. (Figs. 6, 7, 8.)

The substances which have proved most useful so far are derivatives of phenoxyacetic acid. Unlike most other chemical weed-killers, which are usually plant poisons and are used in concentrations of 1 to 10 per cent, these derivatives of phenoxyacetic acid bring about hormone-like growth-stimulating effects when applied at concentrations of 0.0001 to 0.001 per cent; applied in sprays at concentrations of 0.1 to 0.2 per cent they act as plant killers of a new kind. The chemical penetrates the plant rapidly and becomes distributed throughout its tissues. Leaves and roots wither and die, usually in three weeks or less. Applications should be made in warm weather when plants are growing rapidly, and the killing seems to be more effective when treatments are made in the early part of the day. Plants growing in the shade often are unaffected by 2-4-D treatment, whereas the same kind of plant growing in full sun may be killed with one application.

The best established use of 2-4-D thus far is in the control of lawn weeds. Lawns of blue grass or mixed grasses are not harmed by 2-4-D, and when sprayed with the chemical in a 0.1 per cent concentration, common weeds are destroyed (broad- and narrow-leaf plantain, dandelion, chickweed, *etc.*). The chemical should not be used on vegetable and flower gardens, for most garden plants are injured or destroyed, just as are the lawn weeds. Numerous shrubs are also injured by it, but not in the low concentrations which might drift in the wind at the time lawns are sprayed.

The agricultural uses of 2-4-D for weed control are in their infancy. The relative immunity of most kinds of grasses to 2-4-D carries over to the cereal grasses; wheat, barley, corn, oats, rice and sugar cane growers are among those who stand the greatest immediate chance of benefiting, as well as those who grow grass for seed. Most of the important weed infestations in these crops can be controlled with 2-4-D, not only without injury to the crop, but with resulting increases in yield as a result of weed-free fields. Rehabilitation of pastures weedy from over-grazing is also a promising use for 2-4-D.

Power line rights of way present a major problem in keeping down weed trees and undergrowth, and 2-4-D may well provide the answer; roadsides and railroad rights of way also present major weed control problems. In no case should the possibility of injury of field crops adjacent to such areas be overlooked.

A further important line of investigation of weed-killing uses for 2-4-D lies in its possibilities for soil "sterilization". Preliminary work indicates that when applied to bare fields it will destroy the seeds of many common weeds, and crops can be planted after the harmful effects of the 2-4-D are over. Up to now, however, this procedure seems to have its limitations in regions where there is little rainfall, or where rainfall is sharply seasonal.

For work in the field of health, 2-4-D weed killers have great promise. The common and giant ragweeds, hayfever-causers extraordinary, are easy prey to 2-4-D sprays, and applications are lethal almost up to the time the ragweed be-

FIG. 6 (*Upper*). Wild mustard and grass planted in two pots, the left one sprayed with 2-4-D on March 18. FIG. 7 (*Center*). Two days later. FIG. 8 (*Lower*). Two weeks later. (*Courtesy The Dow Chemical Co.*)

gins to loose its pollen to the wind. Plants which cause skin allergies upon touch, such as poison ivy and poison sumac, are also killed by 2-4-D, but with these plants the chemical is not always effective. Because poison ivy frequently grows in the shade, it presents a special problem; the esters of 2-4-D are more effective than the acid in such cases.

Breaking Dormancy with Chemicals

This subject is no longer new, nor are dormancy-breaking chemicals strictly hormones in the presently accepted sense of the term.

It has been known for a long time that the buds of many kinds of plants are dormant for some weeks or months after their period of active growth. Whether a bud is an "eye" of the potato or the winter bud of the lilac, its growth does not continue with equal intensity throughout the year, even though temperature and other factors remain favorable. Buds of most deciduous trees, for example, are dormant for several months in the late summer, autumn and winter, after cessation of the spring and early summer growth. This rest period apparently is brought on by chemical changes in the buds, presumably by accumulation of chemical substances which slow down metabolism and inhibit growth. It is only buds which are in this dormant state, not entire plants. In nature a few weeks or months of cold weather usually serve to break the resting condition of the buds.

Within the past two decades work has been in progress by Denny, Guthrie and others, chiefly of the Boyce Thompson Institute, which shows that ethylene chlorohydrin (and a few other chemicals) can act as chemical substitutes for cold in the breaking of dormancy. Their work has been on potatoes, gladiolus corms and a number of ornametal shrubs and trees. With their methods the period of dormancy can be shortened by one to three months as a result of ethylene chlorohydrin treatments (azalea, three weeks; deutzia, six weeks; flowering crabapple, eight weeks; hawthorn, four weeks; weigela, five weeks, *etc.*). Freshly harvested potatoes treated with ethylene chlorohydrin will sprout about two months before untreated potatoes, and certain varieties of gladiolus gain one to many months by treatment.

The chief opportunity for large-scale use of methods for breaking dormancy in trees is in mild climates where in many winters there is insufficient cold weather to assure the natural breaking of dormancy, e.g., peach orchards in Georgia and California. The greatest success to date in hastening the breaking of dormancy in orchards has come not from the use of hormones or of ethylene chlorohydrin, but from the use of dinitrophenol and dinitrocresol sprays. Applied in oil (dormant sprays), they shorten the rest period in apples, apricots, cherries, peaches, pears and pecans by at least one to two weeks. (Fig. 2.)

Prolonging or Inducing Dormancy by Hormone Treatment

The work on extending the period of dormancy in plants has thus far been directed chiefly toward preventing sprouting of potatoes in storage, prevention of frost damage to fruit and other trees by holding back bud growth until danger of frost is past, and prevention of sprouting of nursery stock while in storage.

The basic work on prolonging dormancy in potatoes has been carried out, for the most part, by Guthrie and Denny at the Boyce Thompson Institute. Their work shows that treatment of potatoes with the methyl ester of naphthaleneacetic acid as they go into storage will prevent the sprouting which ordinarily starts after a few months. So successful is the treatment in extend-

ing dormancy that such potatoes should not be used for seed.

Hormone treatment of fruit trees, tung trees, *etc.*, in order to delay blooming is still in the experimental stage, but the prospects are good. A delay of a week or two in the flowering of such trees would often prevent great loss by frost damage. It might also make possible the extension of the picking and marketing season.

Hormones have also been used successfully to prevent the sprouting of nursery stock of roses while in storage. The methyl ester of naphthaleneacetic acid holds back bud growth in roses, just as it does in potatoes. It may be applied as a vapor or in a wax-emulsion spray. There are indications that similar treatments may prove equally valuable with other kinds of nursery stock.

Chemical Production of New Varieties of Plants

Colchicine can hardly be considered a plant hormone, yet it exercises an effect on nuclear division which makes it a special chemical of considerable importance. Indeed, because of it the traditional methods of cross-pollinating, and of discovering bud sports, are no longer the only important means of getting new varieties of plants. It is now possible to produce new types by colchicine treatment of seeds, seedlings or growing branch tips of older plants. The proportion of useful new kinds of plants to the total treated is not high, but an occasional new form may more than justify much apparently fruitless work.

Colchicine treatment, when effective, results in a doubling of chromosomes, and the resulting polyploid plants frequently possess size, growth vigor or other qualities more desirable than that of the plants from which they are derived. It has also been possible to render sterile hybrids fertile by colchicine treatment, thus making available new types of plants for ordinary breeding work. One large seed company has introduced a new variety of marigold, and more recently of snapdragon, as a result of its colchicine work; and in all, well over 50 clearly new polyploids have been produced by researchers in this field.

Utilization Abstracts

Buckwheat, Rutin and Hypertension. The discovery in 1860 that buckwheat is a source of the flavonol glucoside, rutin, acquired significance in 1944 when it was found that rutin is effective in the treatment of increased capillary fragility associated with hypertension in man. The resultant widespread and increased demand for the drug led to an investigation by scientists of the Eastern Regional Laboratory in Philadelphia, U. S. Department of Agriculture, for possible sources of this drug which, according to preliminary reports, has been efficaceous in certain cases of retinal hemorrhage and apoplexy. Of all the species examined, buckwheat so far is the most promising source of the drug. The rutin for the first clinical experiments was prepared by them from flue-cured tobacco. The glucoside has been obtained from leaves, blossoms and stems of buckwheat, and a yield as high as 8.56% was reported, considering the whole plant exclusive of roots. It was calculated that an acre of buckwheat in 26 days from planting would produce 14.2 pounds of rutin, and 50.25 pounds, or approximately 3.5 times as much, in 40 days. (*J. F. Couch, J. Naghski and C. F. Krewson, Science 103: 197. February 15, 1946*).

Ragweed. *Ambrosia monophylla* (Walt.) Rydb. (*A. paniculata* Michx.) is cultivated in country gardens in the Dominican Republic and is "used for poultices in the treatment of various pains and ills". It is sold for this purpose in the market places of the capitol city, Trujillo. (*H. A. Allard & H. F. Allard, Science 104: 429. 1946*).

The Role of Botanical Research in the Chicle Industry

An American industry which in the last pre-War year did a total retail business of $140,000,000 and has been based largely on exploitation of the sapodilla forests in the Yucatan Peninsula without much concern for perpetuating the supply.

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Introduction

MAN'S propensity to chew—just chew—has resulted in a distinctive subdivision of economic botany, the chicle plants, and has produced a distinctive business activity, the chicle industry. The word "chicle" is a relatively recent addition to our language, and is not included, for example, in American dictionaries on hand, dated 1885 and 1914. Chicle is now defined as the gum obtained from the latex of *Achras Zapota* L., used as the chief ingredient of chewing-gum, and any of several other gums derived from trees of the families Moraceae and Apocynaceae (Webster's New Int. Dict., 2 ed., 1944). For our purposes we can consider chicle as the coagulated latex of *Achras Zapota* and of any other tree used as a basis for chewing-gum, or its synthetic substitute.

For purposes of orientation, we shall briefly consider chicle as a product from plants, chicle as a masticatory for man, Central American chicle as a basis for an industry, and some current trends in American industrial research concerning chicle. This orientation is followed by a conspectus of the past chicle research carried out by private organizations, government and industry, comprising data offered as a historical record of these earliest phases of investigative activity. The paper concludes with an evaluation of future research, pointing out the fields where investigative work might prove advantageous. In all these discussions, it is my purpose to present the chicle problem as a facet of economic botany, in the perspective of its rôle in human activity and in American industry. The economic importance of research will be given special emphasis. It is not the plan of this article to present the botanical details of chicle investigations.

Chicle as a Product from Plants

There are various ways of grouping and relating the products obtained from plants. Each has its own merits. We may classify such products by their chemical constitution (fats, carbohydrates), by their physico-chemical organization (solutions, emulsions), by the tissues from which they are derived (xylem, resin canals, latex tubes), by the phytophysiologic processes concerned

[1] The author wishes to acknowledge the appreciated assistance of R. L. Wilson (Director of Research, Wm. Wrigley Jr. Co.) and R. K. Phelan (Asst. Research Director, Beech-Nut Packing Co.) who checked the manuscript for factual errors, and who offered valuable suggestions. The opinions expressed in this paper, however, are solely those of the author, and do not necessarily represent those of the industry, or of this journal.

The author also wishes to be recorded as not favoring the policy of this periodical in capitalizing the first letter of certain specific scientific names.

(bleeding, guttation), by a laboratory process (solution from tissue by solvents), and by other means. For certain purposes in economic botany, it is well to refer all those substances which are discharged through small pores and openings, and which accumulate on the external surfaces, of plants, as "exudates". Strictly speaking, exudates accumulate naturally through normal physiologic processes or by normal accidents (bark injury). That such exudation may be greatly amplified by man (turpentine and rubber tapping) does not change the nature of the exudate. Likewise, we can still speak of "exudates" if they are obtained by maceration of plant tissues and extraction by solvents.

Five major kinds of exudate may be recognized: (*a*) Liquid water, exuded by guttation from hydathodes, which are leaf pores in close proximity to the ends of xylem vessels, or exuded by secretion from special glands not associated with xylem vessels. (*b*) Saps, exuded by bleeding from broken stems and branches, especially in spring in temperate regions. They are usually derived from xylem tissue, sometimes from phloem, and contain carbohydrates and various other substances. The maple sugar industry in northeastern United States is based on this phenomenon. (*c*) Gums (not including chewing-gum), exuded from stems, branches and fruits. They are amorphous complex carbohydrates which are soluble or which soften in water but not in alcohol. The best known are gum arabic from *Acacia* and *Prosopis*, gum tragacanth from *Astragalus*, and cherry tree gum from *Prunus* and *Cerasus*. They are used in medicine, confectionery and adhesives. (*d*) Resins, exuded from stems, branches and fruits, and often from special resin canals. They are non-crystalline compounds, frequently oxidation products of essential oils, which are soluble in alcohol but not in water. The best known are African copals, Asiatic damars, New Zealand kauri resin, fossil amber, crude turpentine, Canada balsam and frankincense. The insect-derived lacquers and shellacs are chemically related and usually included among resins. Resins are used in varnishes, cements, medicine, incense and naval stores. At times, natural exudates include mixtures of both gums and resins, known as gum-resins, examples of which are asafoetida and myrrh. (*e*) Latices, exuded from broken surfaces of all parts of the plant body. They are complex milky emulsions of granules of various substances suspended in a watery medium in which numerous other substances are also dissolved. The granules include resins, oils, proteids and starch grains. Latex is secreted in special laticiferous tissue, usually in the phloem. This tissue may be composed either of branching coenocytes, which elongate with growth of the plant but do not anastomose, or of anastomosing vessels, formed from the breakdown of the separating walls of individual cells. The families known to bear latex include Apocynaceae, Asclepiadaceae, Campanulaceae, Compositae, Euphorbiaceae, Moraceae, Papaveraceae and Sapotaceae. The best known commercial products from latices are rubber, adhesives, insulating materials, chewing-gums and opium. We are now concerned only with the chewing-gums, obtained originally from the Sapotaceae, but now also from plants of other families, especially the Apocynaceae. Chicle is thus the intermediate commercial product, a stage between the liquid latex of the living tree and the manufactured chewing-gum.

Chicle as a Masticatory for Man

There are various ways of grouping and relating plant products used by man for his own specific purposes. One such group of miscellaneous substances

is known as "masticatories". A masticatory (Fr. *masticatoire;* Span. & Ital. *masticatorio;* Germ. & Dutch *Kaumittel*) is often defined as "any substance that is chewed to increase the secretion of saliva". The rôle of salivary secretion, however, is quite incidental to the act of chewing, and the word might better be defined as "any substance or substances chewed, without intent of ingestion". Narcotic, gustatory, cosmetic, nutritional or other effects may occur concomitantly.

FIG. 1. Area on the Yucatan Peninsula covered by the sapodilla forest (after Lundell).

The study of masticatories, as a field of human knowledge, is still unorganized. A survey of the leading American and European encyclopaedias showed that in no case has a separate article been written on the subject, that the word is generally not indexed, and that at the most only a dictionary definition is included.

The masticatory process, other than that associated with the purposeful chewing of food, is to be allied to various other random and irrelevant movements of man and woman. Such undirected automatisms include incessant and repetitive talking, doodling in all its ingenious manifestations, nail-biting, whittling, foot swinging, fiddling with objects, and the host of other activities that we frequently attribute to "nervousness" and "tension". An understanding of such movements lies in the realm of the psychologist, and the relatively limited research in that field will be mentioned later in this paper. From the cosmopolitanism of the chewing habit, it would appear that such "jawing" and "chawing" is an inherent activity of *Homo.* The action expresses itself in the primitive oborigine chewing an unknown exudate from a jungle tree, as well as in the tailored attorney offering "cocktail chewing-gum" to the debutante of today. Likewise, it expresses itself in the nipple-sucking nursling, through the days of osculation, on into the denture-doodling octogenarian.

Masticatory substances include a vast variety of plant materials, in many countries and among many races. The substances used are of infinite number, varying from raw gums, resins and latices to the finished products of modern industry. In the course of cultural development, certain masticatories have attained widespread regional use. Thus, in the Near East, one tenth of the entire human race indulges in betel chewing. In this bright and relatively modern practice, one chews a homemade package of betel nut slices (*Areca Catechu* L., a palm), a pellet of lime and some aromatic or spicy substance, all wrapped in a betel leaf (*Piper Betle* L., pepper vine). The lime appears to increase the solubility of certain alkaloids in the nut and thus the physiologic effect of the mixture. The resulting copious flow of saliva is brick red in color, dyeing the mouth, lips and gums. The habit eventually turns the teeth black. Pedestrian

expectoration leaves red spots on the streets, certainly a more colorful result than the drab gum blotches on our own sidewalks and subway platforms.

In western South America the chewing of coca (*Erythroxylon Coca* Lam.) is the custom among at least eight million people. In this habit the leaves are chewed together with a small quantity of lime. Coca leaves contain an appreciable quantity of cocaine, and the resulting narcotic effects are intimately linked with this masticatory habit.

In North America the chewing of tobacco was originally an Indian custom. It received a temporary vogue of questionable elegance in the last century, and then experienced a short revival during the cigarette shortage of World War II.

In the spruce-fir regions of the North, resinous exudates of the conifers are used locally. Thus, "balsam gum" (*Abies balsamea* (L.) Mill.) is known in America, Kauharz in Germany, and similar products in Scandinavia and Russia.

From Central America comes the original chicle, a tasteless, highly cohesive, non-narcotic, non-nutritional, coagulated latex, which appears to satisfy in man nothing but his psychologic urge to chew. The original chicle came from a tree known variously as zapote, chicozapote, níspero, sapodilla, *et al.* Botanically the tree has been known as *Achras Zapota*. It is still known by that name in the trade, although the binomial has been changed and other species have been split from it. Adulterants and substitutes have been used, not only from Central America, but from South America, Africa and the Orient, often unrelated botanically to the original *Achras*. The term "chicle" is thus used in both narrow and broad senses. The raw latex is coagulated, processed, combined with other substances, flavored and sweetened, and the finished product is marketed as "chewing-gum." Our interest in chicle, therefore, is that it is the chief constituent of chewing-gum, basis of an American-born industry and an American product, and the use of which was spreading into other countries even before the recent War greatly accelerated that spread.

Central American Chicle as a Basis for an Industry

The chicle demands for chewing-gum production have built up, within the past half century, a huge industry which in the last pre-War year did a total retail business of $140,000,000. At five cents a pack, this figure impressively expresses the more refined chewing propensities of the human race. The chicle industry is curious and interesting in many ways. It is an exploitation industry, "mining" the existing material resources, under circumstances where renewal by further growth is negligible or entirely non-existent. Production is continued largely by discovery of new virgin areas and of new sources. As such, the latex industry has no bright future, if any at all, although the inevitable end to the draining-of-the-bucket may be postponed by sundry "conservation" measures. We shall sketch certain phases of this industry under five headings: (*a*) the geographic aspects; (*b*) the forest and the tree; (*c*) the latex; (*d*) the chiclero; and (*e*) the administrative organization.

The Geographic Aspects. The chicle industry is primarily American in its finances and administration, but pantropical in its field activities. The sources of gum have been, and are, relatively numerous. Jelutong (*Dyera*, Apocynaceae) comes from the East Indies and Malaysia. Sorva (*Couma*, Apocynaceae) and balata, pendare and massaranduba (*Mimusops*, Sapotaceae) come from Brazil, the Guianas, Venezuela and Colombia (Vander Laan,

1927). *Ficus* (Moraceae) from Africa may soon become a significant source. Chilte (*Jatropha,* Euphorbiaceae) is from Mexico at middle latitudes. The original chicle, however, is from a relatively restricted area on the Yucatan peninsula of Central America, comprising parts of Mexico, Guatemala and British Honduras. In each general area there are various substitutes and adulterants. Pre-War imports of jelutong into the United States exceeded those of chicle for the years 1937–1941. The War entirely eliminated the supply from the Far East, and manufacturers made up the deficit by increasing the purchases of true chicle and by utilizing the South American gums (Overley & Griffith, 1946). A small amount of jelutong was imported in 1946 but only from pre-War supplies that had been stored under water to prevent oxidation and spoilage.

FIG. 2. (*Left*). The effect of mule "grazing" in northern British Honduras. Because of the absence of suitable grasslands for forage, the chiclero, or latex collector, feeds his animals on the leaves of the ramón tree which he either cuts down or climbs to lop off the branches. The tall tree at the left center has been pruned for this purpose; the tree at the right center has not yet been shorn.

FIG. 3. (*Right*). A forest of cohune palm (*Orbignya Cohune* (Mart.) Dahlgren) on deep and fertile soil. Such sites in northern British Honduras are most suitable for agriculture and for forest plantations. The nuts of the cohune palm yield an oil, similar to that of the coconut, which is becoming of increasing importance.

The relatively small Yucatecan area in Central America has been—in the history of the industry—the chief and most reliable source of chicle. This publication is concerned specifically with that Central American region and treats only incidentally of the industry in other regions. Geologically, the Yucatecan area is a limestone plateau, seldom more than 200 meters (650 feet) above sea level. It is essentially flat. Streams and lakes are scarce, although in the

rainy season swamps may predominate over vast areas.

Climatically, the region is characterized by a dry season extending from February to June, with a total annual rainfall grading from 40 inches in the north to over 100 inches in the southern part of the chicle forests. Archaeologically, the entire area was one of the last outposts of the highly developed Mayan Empire, with cities containing over 300,000 inhabitants and a total peninsular population of possibly three million people. The Empire was already decadent when the Spaniards entered, for reasons still unknown. Ethnographically, the area today contains only 10,000 inhabitants, chiefly Indian though variously diluted with many other breeds of traveler. Health conditions are not favorable. Dysentery is omnipresent, and malaria incidence in the area has been the heaviest in all of Central America. Old people are not to be seen.

The Forest and the Tree. In Mayan times, it would appear, the entire peninsula was cleared and under agricultural use. The more or less continuous jungle of today is thus a "young" forest, with what in this country would be called an "old-field" background. I personally find it impossible to accede to the opinion that the present forest owes many characteristics to this Mayan abandonment, and that the chicle tree is unusually long-lived, with many individuals dating back to Mayan times, "being at least a thousand years old." In my own opinion the Yucatecan jungle is a mosaic of communities, each representing some degree of development following a hurricane, or more rarely a fire. This jungle today is composed of over 100 kinds of forest tree. The trees are distributed with such irregularity, in terms of small quadrats, acres and square miles, that statisticians interested in describing populations in terms of "random" and "contagious" distributions would benefit by their study. The understory is dense, but not impenetrable, composed mainly of young trees. Trails are necessary for mule travel. Palms are frequent. The major forest canopy is 75 feet tall or less. Lianas are common, but by no means do they ape the Hollywood jungle of Tarzan fame. Above this general canopy rise the two jungle giants, mahogany and sapodilla, distributed sparsely, seldom more than a dozen to an acre.

The sapodilla tree plays a rôle in the forest to a great extent still unknown. In my opinion it gets a start in openings, windthrows and wherever else there is light. If overshadowed while still young, the tree can persist, growing slowly, dying back, becoming covered with epiphytic mosses, perhaps lasting through half a century. When it does reach the upper canopy, it develops to its full height, sometimes over 100 feet, with diameters of three and four feet. I have never seen a large tree that appeared to have died naturally other than by windfall. With those dead from chicle tapping, the spot is taken over by any of a hundred odd species; most rarely is *Achras* one of these species.

Achras Zapota is well known to tropical agriculturists of both hemispheres, not for its latex or its timber, but for its fruit. The tree when planted in the open becomes highly branched and produces very little latex, but provides an abundance of thin-skinned fruits that are highly relished among native populations.

The Latex. Latex occurs in a system of laticiferous vessels in the bark of the tree. The function of latex in the physiology of the tree is not yet satisfactorily understood. It probably serves numerous rôles, acting as a vehicle for transportation, as a storage for excretory materials and as a protective covering on wounds. The latex exists under pres-

sure within the vessels, this pressure varying with the season, the time of day, the general site conditions and the individual tree. Once the latex is artificially drained from the vessels, they remain dry and do not secrete new latex. It is only after five or more years, when new phloem has developed with new latex tubes, that a sufficient quantity of latex is present for retapping.

The chiclero, or latex-gatherer, using a machete (a typical Latin-American cutlass, with a blade over two feet long) tests various trees by whacking at the base until a suitable yielder is found. Then he starts "tapping" the tree by making a diagonal incision into the bark, almost always into the wood! A second diagonal is started about 12 inches from the bottom of the first and at right angles to it; then a third such diagonal. Next he climbs the tree, using rope and spurs, making a series of such incisions up to the first branches. The diagonals extend around the trunk, sometimes meeting in back, thus ringing and kill-

FIG. 4. (*Left*). A chiclero tapping a sapodilla tree. Note the chicle bag near the base of the tree, into which the latex trickling from one groove to another collects. (*Courtesy of Wm. Wrigley, Jr. Co.*)

FIG. 5. (*Right*). A chiclero tapping a sapodilla tree. Note the scars of the first tapping on the upper part of the trunk. The incisions are made by means of a machete. (*Courtesy of Wm. Wrigley, Jr. Co.*)

ing the tree. In any event, the injury is serious. Triangles of bark die back; often entire panels between diagonals die. The average tapping-age of a tree is 2.5 tappings or less, with tappings at least five years apart.

On cutting, the latex runs down the central zigzag line. This latex is a smooth milky-white liquid without noticeable inclusions or foreign bodies. It is of varying consistency, depending upon the season, usually thin enough to run freely. When some is placed on the palm of the hand, it can be rubbed up into a small ball, through absorption of the moisture into the hand. This balling is often of value for testing the suitability for chicle of unknown latices. A certain amount of the latex remains in the cut, where it dries and stiffens, and from which it can be peeled off in narrow white strips. Such congealed latex is a tasteless masticatory and was undoubtedly used as such by the original Indians, although there is no indication that such chewing ever became the slavish habit that has since fixed itself upon the more advanced civilizations.

In present tapping procedures, the latex is collected in a rubber bag on the ground at the bottom. Each tree yields from one to two pounds of liquid latex. These bags are collected later in the day and brought to the main camp. They are then emptied into large kettles, sometimes mixed with certain amounts of water, placed over a slow fire and constantly stirred. When the coagulation and cooking has sufficiently thickened the latex, it is poured into wooden molds and allowed to cool and harden. The remaining moisture content is an important factor in the price received for these chicle blocks. The blocks are wrapped in canvas and then await transportation.

In days of mule travel chicle was brought in the dry season over long and winding trails which would take two weeks for distances now covered in one-half hour by air. Two decades ago a road was opened west from the British Honduras border and used by Mack trucks. This temperate-region technique, however, was very expensive, usable for only six weeks out of the year, and was soon abandoned. In Mexico a kind of railroad was used at one place. The airplane, however, solved problems with relatively small initial expense. Today, airfields are scattered over much of the peninsula, putting practically all the chicle areas within one mule-day of a plane. Plane service today is very efficient. In 1942, however, the author wobbled over part of Campeche in an open-cockpit plane with a passenger cabin limited to four by the American manufacturer. Said cabin, however, with seats removed, contained a complete layer of sacks of corn, plus eight men, plus sundry fowls nestled in the interstices. Today almost all chicle is flown to the ports, of which Puerto Barrios serves for Guatemala. From the ports the chicle is shipped to the States for manufacture.

In the manufactories, the chicle is first dried, then melted and centrifuged before further use. This centrifuging frees the chicle from bark, leaves, stems, sand and other extraneous material with which it might have become contaminated. A base, or insoluble cud, of chewing-gum is then formed from 0–40% of true chicle, with the balance composed of jelutong, sorva, pendare, perillo, massaranduba, as well as various synthetic resins and elastomers. The insoluble centrifuged base is combined with powdered sugar, corn syrup and flavor, in 100–200-gallon double-bladed mixers, and then removed to a kneader. The kneader extrudes a thick sheet of gum into a train of reducing rolls called a "sheeting machine". After sheeting to requisite thickness, the chewing-gum is next put through scoring rolls which

mark the sheet into the regular sized sticks. At the wrapping machine the scored sheets are broken into single sticks which are wrapped in the machine at the rate of 160 five-stick packages a minute. These are then boxed and cased for shipment. The finished chewing-gum contains about 20% by weight of the insoluble base, 60% of sugar, 19% of corn syrup, and 1% of flavor.

The Chiclero. The chicle-gatherer, or chiclero, is the most colorful figure in the chicle industry. This individual is drawn either from the scattered Indian settlements in the interior, or from the coastal cities. His employment is seasonal, lasting only through the rainy June-February period. During this time he makes more money than he otherwise would all year. Like any other human being, the chiclero spends freely and liberally while off work, and is only too glad when the next rainy season comes around.

In many cases the chicleros and their families now stay at permanent settlements in the interior, living casually through the dry season. Carmelita is such a settlement, having developed almost entirely since construction of the airport there. These settlements are collections of "bush huts", dwellings with pole sides so widely spaced that windows are quite unnecessary, dirt floors, and thatched roofs of palm leaves that are geometrically attractive from the inside. Kitchens are usually in a lean-to, or a separate structure, and cooking is done over an open fire on a table packed with earth. Latrines are unknown. What would be their contents serve immediately as food for chickens, pigs and dogs, thus completing the food cycle far more directly than with the Chinese farmer who fills a latrine to fertilize his garden, to grow his crops, to feed his chickens, to feed himself. The water supply is not up to modern standards. It is generally a water hole at the center of a large shallow depression in the regional heavy clay soil. At one settlement, the water hole had been fenced in, perhaps originally for purposes of sanitation. Actually, cattle were enclosed within to utilize the lush grass, and a trail beside the enclosing fence served as a town-latrine, nighthawk-nest style. The trail, however, was always cleaned once a year during the rainy season, by surface wash towards the water hole. Lest these ideas of sanitation sound extravagant, it may be said that the author has seen numerous comparable instances in the tropics of both hemispheres, and that 50 years ago, some of the best private homes in crowded downtown New York were only in the latrine stage, for which the backyard chiefly served. In recognition of these unsanitary conditions, I am told that during the manufacturing processes the gums are washed thoroughly, and sterilized at high temperatures with a resulting bacterial count well within legal requirements.

During the chicle collecting season, the chicleros live in temporary settlements in the jungle, under conditions relatively more crude. Rains are frequent, though not incessant; atmospheric humidity extremely high; mud is everywhere, indoors and out; fungous skin diseases are rampant; and water holes are sullied by the mules.

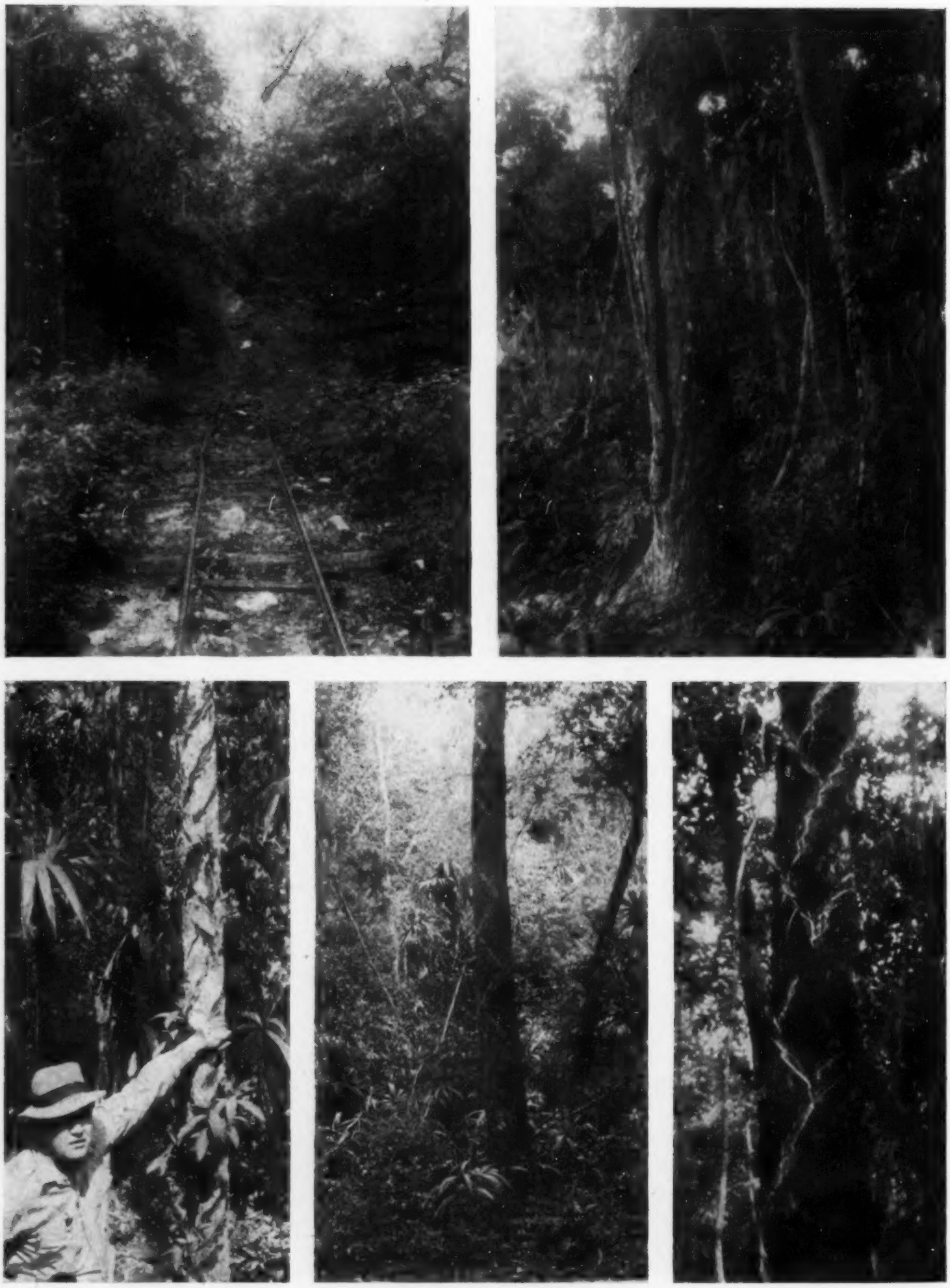
Mule feed in the chicle forests has

FIG. 6. (*Upper left*). Tapping cuts carefully made, apparently without injury but actually resulting in partial death of the underlying cambium.

FIG. 7. (*Upper right*). The bark below the left-hand cut in Fig. 6 has here been removed, revealing a dark area of dead cambium, about 6 × 2 inches.

FIG. 8. (*Lower left*). Trunk showing extensive vertical tapping injury, healed over but enclosing considerable decay.

FIG. 9. (*Lower right*). A twice-tapped tree showing a minimum amount of bark injury.



become a critical problem. Natural grasslands in this area are unknown, and there is no herbaceous undergrowth in the jungle suitable for forage. On air strips and village streets a turf of palatable Bermuda grass (*Cynodon dactylon* (L.). Pers.) may come into existence. Elsewhere "potreros" may be planted of *Panicum* spp., which soon develop into a dense and relatively stable grassland. Frequently, corn has to be flown in to supply the necessary feed. Most commonly, however, while at temporary camps the mules subsist on the foliage of the ramón tree (*Brosimum alicastrum* Swartz). This tree has been reasonably common and is one of the largest jungle trees. The chiclero generally climbs the trunk, lopping off all branches up to several inches in diameter. After such pruning a tree may be reduced to something resembling a telegraph pole, perhaps with one or two stubby branches. The tree apparently sends out new shoots which will again be lopped on attaining suitable size. Basal sprouts are unknown. Dead ramóns in the vicinity of camps, however, indicate that the treatment is too drastic for indefinite survival. Smaller trees up to six inches in diameter are generally chopped down entire, with blissful disregard for the future supply. At the present time the supply of ramón feed is drastically reduced, even though it would be a relatively simple matter of cooperation to develop an orchard of pollarded trees that would produce a suitable crop each year.

The diet of the chiclero is extremely restricted, and probably this situation accounts for much of his poor health. Tortillas (corn-flour pancakes), coffee, and red beans are his staples, eaten three times a day. Rice and wheat-flour biscuits are often cooked. He is generally strongly averse to all other fruits and vegetables. Mangos, bananas, papayas, coconuts, breadfruit and garden crops are relatively unknown. Canned meat is a delicacy, although wild forest game (parrot, boar, pheasant) is liked, as well as the occasional home-fed chicken and pig. While in the forest, game not immediately eaten is often temporarily preserved by barbecuing. In this process the animal is prepared, impaled and suspended over a slow fire where cooking and drying extend over several days. In due time the carcass acquires the hue, consistency and tenderness of an Egyptian mummy, and may be kept thus for varying periods, depending upon the moisture content of the atmosphere.

The chiclero's idea of agriculture at his year-round home is one of the most primitive of the tropics. A section of forest is cut one year and burned the next. A new "milpa" (corn field) may be littered with huge unburned logs, deep holes left from the burning out of stumps, temporarily sterile spots deep in ashes, and lush weed sprouts, all

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FIG. 10. (*Upper left*). Narrow-gauge tracks for transportation of chicle latex from La Gloria to San Dimas. The "train" consisted of a mule-pulled flat-car, and served a region of Campeche now largely depleted of chicle.

FIG. 11. (*Upper right*). Tapping injury involving the death of three consecutive panels of cambium and the entrance of decay.

FIG. 12. (*Lower left*). Typical tapping of undersized tree at Campeche. The person is E. A. Sterling. (*Courtesy of James D. Lacy Co.*)

FIG. 13. (*Lower center*). Scars from the first tapping of a typical sapodilla tree. Various cuts near the base indicate where chicleros had previously tested the tree. (*Photo by E. A. Sterling, courtesy of James D. Lacy Co.*)

FIG. 14. (*Lower right*). White latex flowing down the zig-zag incisions of a freshly tapped tree. The long object inserted in the bark for comparison is the three-foot blade of a machete used to make the incisions.

creating such a scene of confusion that one may be excused for not immediately recognizing the site as crop land. Corn is planted in holes poked into the ground with a stick. When the weeds become too dense they are cut with a machete. By the second or third season the new jungle is huskier than the chiclero, and the area is abandoned on the rationalization that the soil is "worn out". Plows are unknown, either man-drawn or mule-drawn. On several occasions I have heard reputable North Americans claim that plows have been sent in, uselessly, as the local mules do not know how to, and will not, draw a plow. These interesting comments—if proven—might be evidence for the inheritance of acquired characteristics in our North American animals, or at least for the superior intelligence of one breed or the other, depending on one's point of view.

The Administrative Organization. In organization the chicle industry is a Topsy-grown creature, easy to criticize but difficult to improve. Governments, landowners, companies, contractors, subcontractors and chicleros all come in for their own independent pound of flesh, with the result that a pound of chicle becomes really high priced. With these several egocentric interests, the welfare of the chicle tree comes last, if at all. Perhaps we should not object too quickly to this short-sighted attitude toward the goose that is laying the golden egg. The chicle industry, under its present administrative organization, is one in which it is openly a matter of you yourself murdering that goose; for if you do not, someone else will.

The sapodilla forest is partitioned among three countries, Guatemala, Mexico and British Honduras. In Guatemala the lands are all in the public domain, and large territorial concessions have been made to the two American companies within which each can direct operations. This situation is changing rapidly. In May, 1946, the Guatemaltecan government sponsored the first chicle coooperative, and in June, 1946, the government authorized the formation of an independent local company, to operate on the same basis as the American concerns. In Mexico some of the land is public, and some is held by large land-owning estates. In British Honduras most of the chicle land is locally owned by private interests, some is held as colonial forests. In all three countries various regulations and rules have been passed which are thought to insure the future of the industry. Such regulations concern the minimum size of tree for tapping, period between tappings, restrictions on tapping of limbs, limitations on total quantity taken from a certain area, and provisions for several-year rest-periods for the tracts. Because of the problem of supervision in most cases, these regulations can seldom be enforced, except on small privately held areas, and even then it is often difficult.

The various American companies are only buyers of chicle. A major part of the industry is divided between the Wrigley interests, on the one hand, and American Chicle (makers of Chiclets) and Beech-Nut Packing Co., on the other hand. These last two have operated jointly in Central America as the Chicle Development Company. Various small independent companies make up the balance. All the companies purchase directly from the owners of the private Mexican estates, or they negotiate with the "contractors" who agree to operate in the territory of the company's concession and to turn over the chicle to company representatives at some jungle base. The companies have financed the airports as part of their transportation system and have arranged various inspection techniques to catch adulterants, inferior chicles, excessive water content and, in older days weight-increasing

stone content. Although it is to the company's advantage to maintain the forest in a productive state, they have no assurance that the concession will continue to be granted to them or that the same contractors will sell to them another year, or will employ the same chicleros.

The contractors are local citizens, sometimes risen from the ranks of the chicleros themselves. Each year the contractor hires a group of chicleros, advances them a certain amount of money with which to buy equipment and supplies, and often provides them with certain materials. Contractors may be allotted a certain area within a company's concession, or they may go out until they find a likely territory and "stake their claims" for the season. Contractors often sell for years to the same company, but they are under no obligation to do so, and it is to their advantage always to sell to the highest bidder. In turn, the contractor can not afford to think of the future of the forest, for if he himself does not kill that goose, there are a dozen others that are ready to do so.

When we consider the chiclero, we realize how impossible it is to regulate the industry for the good of the forest. The trees are scattered 2–12 to an acre. The chiclero goes out one time locating trees. Then he goes out to tap them. He map be able to tap about eight trees a day, but he so works only 15–18 days a month. The remainder of the time is spent in locating the trees, in idleness due to excessive rains, or in cooking the chicle. Thus, in a season of seven months, a chiclero works, on an average, only 126 days. He is paid per pound of chicle. There are other chicleros from the same camp just as eager as he to get the pounds. There are chicleros from all neighbouring camps, also as eager. And next year he may be placed far away in some other area, never to return to this place. With the trees so widely spaced, supervision is impossible. Consequently, no one will know just which tapped trees are his own work. His response is that of any intelligent human being. He gets as much latex as possible in the quickest possible time, with the least expense of energy, from any size tree, regardless of damage to the tree and the future supply. Any conservation measure that cuts down his own production only means more latex for some nearby less ethical chiclero—and there always is such a one. This is no criticism of the chiclero, but of the system which does not, or can not, or will not, give the chiclero sufficient protection so that he can "afford" to practice conservation.

In conclusion, the fact that the industry is spread so thinly over such a large territory permits all sorts of evasions of whatever regulations may be passed. Individual chicleros carry on a certain traffic in chicle between themselves, unknown to the contractor. This is advantageous to the chiclero if he obtains more chicle than agreed upon, either from underlimit trees or from adjacent tracts. Large private properties are difficult to patrol, even if the boundaries have been opened, and it is always to the advantage of the contractor to get chicle in the easiest most convenient manner. Consequently, production figures from the different estates are not always reliable. Furthermore, the unpatrolled international boundaries offer even greater inducements for evading regulations. For example, a small section of one country has been fairly well depleted of chicle by gatherers from the adjacent country. Furthermore, at some trail-crossings, international borders have none of the expressions of authority we usually associate with them. Even nearby settlements often have no evidence of civil authority. It is said that certain ones have crossed


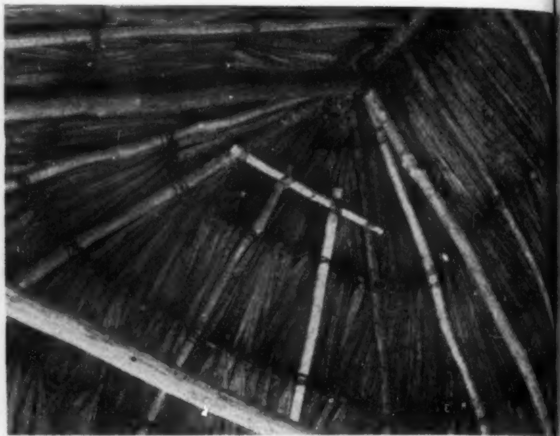

FIG. 15. (*Upper left*). A typical open-fire cooking table in northern British Honduras. The fire is built directly on the marl-packed table, and the grill is made from scrap metal.

FIG. 16. (*Upper right*). The interior of a typical bush-hut in northern British Honduras. Note the lianas used for tying the structure together, and the neatly arranged rows of palm thatch.

FIG. 17. (*Lower left*). The town of La Gloria, Campeche, with the terminus of the San Dimas "railroad" at the left foreground. Deep mud marked the central "plaza", though the picture was taken in the dry season.

FIG. 18. (*Lower right*). The author's bush-hut headquarters in northern British Honduras. Only vines and lianas are used to hold the structure together. Sleeping hut at left; kitchen hut at right.

and recrossed such borders, and stayed in a country for varying periods, without benefit of formalities, visas and permits, neglect of which in normal situations has produced interesting effects. For all these reasons, production figures from the countries themselves are often unreliable and may give misleading indications of the state of the industry.

Some Current Trends in American Industrial Research

Before proceeding to a discussion of chicle research it will be well to scan the general field of American industrial research. Chicle investigations are a small though significant element of this total American scene, and can not be interpreted properly without reference

to the whole. Furthermore, it may be assumed that more and more will the chicle research of the future be influenced by the entire industrial picture in this country. The current and rapidly changing status of three aspects of this subject are considered in the following paragraphs which deal respectively with research in general, American research and American industrial research.

We live now in a day of complete reorientation toward research. There used to be an unbridgeable gap between "applied research" and "pure research". Applied research was once carried out in more or less of a trial-and-error method, without organization and continuity. Pure research was an out-and-out luxury, to be indulged in by that socially useless minority who had sufficient means to putter in an ivory tower. Society throughout the world did not object to such activity, neither did it encourage it. Perhaps history will recognize August, 1945, as the turning point in civilization's attitude toward that pure research. In a few awful seconds the entire world was allowed to learn that the intellectual putterings of several generations of those "pure scientists" had become the most potent mass of practical knowledge that any government, or people, or group ever possessed. Almost overnight the new "basic research" caught on, and is today supported in many countries in a manner undreamed of by the pure scientist of other years. I do not at all intend to imply that the pure scientist has now become an applied scientist, working for immediate and recognizable technologic goals. To the contrary, the psychology of the pure researcher remains unchanged; it is only that the practical man, gaining by hindsight, has increased his foresight, and is now openly exploiting the products of that ivory tower. As such he looks upon the matter as a very profitable undertaking. This new combine of personnel is entirely logical. "I suppose that the reason digging for truth is not only more interesting, but more profitable, than digging for gold is that if urged on by the love of digging, one digs more deeply than if searching for some particular nugget. Practicality is likely to be shortsighted and looks so hard for some single objective that it may miss much that nature presents to one who is purposely digging for whatever may turn up"[2]. The import of all these current research trends to the chicle industry is both interesting and instructive.

American research had progressed significantly though slowly, before 1940. In 1930 the nation spent $166.1 millions for all research, including industry, government and university. In 1936 the figure had risen to $218.1; in 1940 to $345.2, of which $69.1 was government research. In 1942 government research alone had become $332.1, and in 1944 it was up to $719.8 millions. The combined research and development program of the federal government is today as large as, and in certain instances larger than, during the war. Current expenditures are at about 20 times the 1940 level, and for the first half of 1947 they will be at the rate of $1,500 millions, exclusive of the Manhattan project. On the other hand, the rôle of fundamental studies in the early history is not so creditable. In several respects, American science can take little pride in its past performance of basic research. Even though we have been preeminent in the application of fundamental knowledge to practical problems, a large proportion of the original discoveries have been made abroad. If the awarding of Nobel prizes is an indication of active basic research, it should be significant that we have received only one out of seven such awards in the fields of physics, chemistry, medicine and physi-

[2] Harrison, G. R. Science 103: 125. 1946.






FIGS. 19, 20, 21. (*Upper row & Center left*). The main street in Carmelita, Peten, a typical native village of the Yucatan Peninsula.

FIG. 22. (*Center right*). Interior of a Douglas DC2 used for transporting chicle out of the jungle. Each bag contains about 150 pounds in irregular blocks of gum, and the usual flying load is 5,000 pounds.

FIG. 23. (*Lower left*). Airplane field at Villa Hermosa, March, 1946, showing the antiquated single-motor plane used for transporting chicle 150 miles to the coast.

FIG. 24. (*Lower right*). Loading chicle at Carmelita. (*Photos 19–24 by E. A. Sterling, courtesy of James D. Lacy Co.*)

ology. Although figures for national basic research are not available, we can observe trends from other sources. American university research, constituting the main stronghold for basic studies, cost only $20.3 millions in 1930, $25.0 in 1936, and $31.4 in 1940. In 1945 both houses of Congress argued the

pros and cons of a National Science Foundation, one important function of which was to encourage such basic research. This Foundation was estimated to cost $33.5 millions in its first year, and $122.5 when it reached stability in its fifth year. While Congress disputed the details of the Foundation, the Army and Navy embarked on their own programs, believing in the necessity of immediately supporting such fundamental studies. In 1945 alone the Army and Navy expended about $140 millions for basic research in universities and laboratories. For the Navy this involved some 90 contracts, covering 235 projects, 70 per cent of which are with universities. Government sponsoring of basic independent research is by no means limited to the military. As one of several possible examples, the U. S. Public Health Service Research Grants now total $3.9 millions for a period of less than a year. They involve 264 research projects in 77 institutions, and are granted to independent scientists, with remarkable freedom from control and regulation. It would be assumed that these changing forces would be reflected by parallel trends in the chicle industry.

The history of American industrial research also shows an interesting accelerating curve. Research expenditures by industry in 1920 were only $29.4 millions; in 1930 $116.0; in 1936 $152.0, and in 1940 $234.0 millions. There are now said to be 2,264 industrial research laboratories in this country, although many of them are probably only developmental and trouble-shooting offices. On the other hand, both pineapple and sugar industries in Hawaii have for years sponsored cooperative experiment stations on a lavish scale. The industry-sponsored Sugar Foundation in North America has an exceptionally large research program. We find more and more corporations establishing the position of Director of Research. This person now is frequently an integral executive with the title of Vice-President in Charge of Research, to wit, C. E. Kenneth Mees of Eastman Kodak Co., and the nationally known C. F. Kettering of General Motors Corporation, recently President of the American Association for the Advancement of Science. Several years ago Dr. Compton told the National Association of Manufacturers that two per cent of the gross income of any industry could be expended effectively on research, a figure which might be applied with interest to actual current research expenses of the chicle industry. It is true that "industrial research traditionally has consisted primarily of developing and perfecting the application of fundamental discoveries made in the non-commercial laboratories. . . . If the universities [however] are not enabled to carry on their fundamental researches at a pace commensurate with the need, then industry, as a matter of self-protection, will have to devote increasing attention to this type of research problem. . . . Before this type of investigation can be pursued by industry to an adequate degree, management will have to be convinced of the necessity of such studies. The directors of research will have to demonstrate to Boards of Directors that money spent in such research is as productive in the long run as is applied research designed for immediate commercial application"[3].

Today we find numerous expressions that such fundamental research is now becoming a profitable undertaking for some of the larger corporations. For example, the Escuela Agrícola Panamericana in Honduras is supported entirely by the United Fruit Co. This agricultural school is for training young men in all fields of tropical agriculture, and for research in a variety of tropical food plants. Corporations like Bell Telephone, General Motors and General

[3] Tainter, M. L. Science **103**: 95. 1946.

Electric are sponsoring fundamental research with a thoroughness never before expressed. Coupled with the realization that the functioning of basic research must depend on properly trained personnel, industry has stepped into the field of assisting in that training. For example, Merck & Co. has recently announced (Nov., 1946) an appropriation of $100,000 to support a series of postdoctorate fellowships with unusual latitude in choice of the field of research and with freedom of publication of results, coupled with opportunity for advanced courses of study. The new "Industrial Research Laboratories of the United States" lists 302 companies which are providing fellowships, scholarships or grants of research, to all of which are accorded a large degree of freedom. These funds are distributed in some 1,800 grants, representing an expenditure of probably more than $10 million per year. This large sum is about half that which was spent for all research in all universities in this country in 1930! With this handwriting on the wall, it appears as though American industry has committed itself, not only to a sizable program of applied research for immediate benefit, but also to a farsighted long-range policy of basic research. The influences of this national trend on the chicle industry will undoubtedly be of great interest.

Past Chicle Research

It is often useful to consider research as being carried out by three agencies: private organizations, government, and industry. The investigations by private organizations, such as research institutes and universities, are not readily separable from numerous fundamental researches in allied laticiferous plants, including rubber and its substitutes. Various students of J. S. Karling have worked on latex and latex vessels of plants other than *Achras* since 1926. Independent research on *Achras* itself, however, is more limited. Several large landholding estates in Mexico have issued reports based on sampling techniques, as a basis for their exploitation programs. It is well to mention here that T. H. Everett, Horticulturist at the New York Botanical Garden, has succeeded in rooting *Achras* cuttings by air-layering. Such rooting, hitherto unreported, may be one of the most important single factors in establishing plantation trees in the dense and rapidly growing tropical undergrowth. In a different category entirely are the precise psychological studies, such as that of Hollingworth on the relationships between chewing and metabolism, strain and work efficiency. These studies provide evidence that chewing reduces tension, reduces the energy that otherwise is wasted in various random movements, that the chewing itself absorbs only a small amount of this saved energy, and that some of it is actually discharged into the main occupation. What impressive advertising slogans may lie in studies of this kind that may be carried out in the future!

In respect to the second agency, governments, I am not aware that either Guatemala or Mexico has carried on any investigations other than possibly certain surveys and inventories leading to the more or less arbitrary establishment of rules and regulations supposedly conserving the supply of chicle. In British Honduras the colonial government has exhibited a more far-reaching policy and has not only cooperated with industry but has carried out certain researches of its own. In the main these have concerned techniques of tapping and have been based at the Freshwater Creek Forest Preserve in the northern part of the colony. To my knowledge the researches have not yet yielded significantly valuable results.

Thirdly, in industry-sponsored chicle

research we come to an interesting and instructive phase. In the first place we must distinguish between botanical research on chicle-yielding plants and chemistry research on synthetic substitutes. Synthetics research remains largely intra-company information and is beyond the scope of this article. During the last War a popular chewing gum is said to have been at least three-quarters synthetic, and though it has now been removed from the market as inferior, the possibilities of a suitable synthetic are very real. Although at this time such possibilities must have repercussions on the interest in botanical research, this was certainly not true in previous years.

Industry-sponsored botanical research can bear division into two groups, based, respectively, on the two leading companies in the industry. One of these took the stand a quarter of a century ago—and with considerable justification—that experiment station research is not practical for chicle. Other than a limited amount of area-cruising, that company has entered on no botanical investigations within its research division. The other company has engaged in research; it has followed a liberal policy of publicizing the results of this research, believing that it is to the benefit of the entire industry to do so. It is on the basis of such public records that the following statements are made.

The entire significant history of chicle research, despite its violent fluctuations, is encompassed in a mere quarter of a century. In 1921 Mr. Hummel, then Forestry Officer of British Honduras, published his "Report on the Forests of British Honduras, with Suggestions for a Far Reaching Forest Policy". This policy recommended a conversion of the native jungle to a sapodilla plantation. The results of the passage of time indicate that Mr. Hummel is more to be commended for his high-pressure salesmanship than for the professional worth of these unique silvicultural theories. He sold his idea not only to the industry officials, but to the entire colonial Forest Office—though not to other interests. A forty-thousand acre tract was privately purchased in 1924, and operations were begun in full intensity and with the hearty cooperation of government. Brief reports on these forestry operations appeared in the Annual Reports of the British Honduras Forest Trust through the year 1928. By that time, however, it became apparent that expected results were not being obtained. Thus this unfortunate project—questionably to be designated as "research"—was completely abandoned. To my knowledge, the negative results were not reported and evaluated as a technical project, and the conclusion was psychologically fixated that sapodilla was not, and would never be, suitable for plantation development.

The next investigation venture was more successful in scientific worth, if not in immediately applicable results. Dr. J. S. Karling of Columbia University, working for industry through the Tropical Plant Research Foundation, and on the same 40,000 acre tract, carried through a five-year (1927–1932) series of tapping investigations, all important results of which appeared in several articles by Karling and by Lundell. At Dr. Karling's suggestion that the tapping studies be discontinued, it appears that not only they but the entire investigative structure in British Honduras collapsed, apparently with the abandonment, loss or misplacement of various materials and records.

It was almost a decade later that the future of the industry again began to weigh heavily on certain minds. The author was borrowed from his university for intensive field surveys in Central America, and on the basis of his recommendations, an Experiment Station was

established. This station was not only to embark on an active research program on termination of the War, but was to serve as an administrative research unit within the industry, to ride through expected waves of interest and disinterest, and to serve as a continuous medium for preserving the records, files and information of importance to research. The short life of the Station is reflected in three mimeographed reports, copies of which are in the British Honduras forest office, and in three published articles by the author. The author resigned as Director in October, 1944. No successor has been appointed, and assumedly the Station has lapsed into non-existence. Once again a stasis was obtained.

Connecting and anastomosing among the threads of these three chapters are a series of short-time projects, often creditable, sometimes carried to completion, sometimes abandoned as soon as results began to appear negative. These projects have been carried out on a retained consultant basis or on short-term assignments. In this category are to be placed various surveys and investigations by the James D. Lacey Co., to ascertain the amount of exploitable chicle in the forests, a popular report of which was published by Sterling. In addition, there are sundry taxonomic investigations that have appeared by Cronquist, Gilly and Monachino. Even in its taxonomic work—one of its few ventures into basic research—the industry has not always obtained results that encourage it in this line. For example, Gilly has found good and valid cause to abandon the fine old name of *Achras Zapota*. In addition, however, this old familiar sapodilla was disrupted into ten species, plus varieties. These segregates were recognizable only by flower characters—a pesky situation for the field man, for the tree is usually flowerless in nature and in the herbarium. Scarcely had the significance of this complexity begun to be absorbed when Cronquist, approaching the problem from other and more conservative standards, reduced the ten species to three. Verily, when the gods themselves dispute, whom is the common man to follow?

Within recent months, there have been numerous changes in the policies of the companies regarding research. Reports are conflicting and often contradictory. In general, it appears that research on *Achras* is completely halted, but that an investigative program on other natural gums, especially jelutong, has been and is in process of formation.

As we glance backward we see that the lavish and unlimited exploitation of natural resources has started to raise some wrinkles on the brows of the more far-sighted. Continued opening of virgin areas, however, has caused others to take such fears and worries quite lightly. The real nature of scientific research and careful preliminary application of research results are not in my opinion yet segregated from strip surveys for estimating existing quantities of chicle. Nor are they segregated from the desire for a plunging all-out offensive, à la Hummel, such as would put the industry on a permanent basis, overnight, or at least as quickly as man-hours could be applied. The actual research, if one desires to call it that, has too often been encompassed in such a phrase as "How much chicle can be taken out of a given area without jeopardizing future production?" This question will always stymie field botanists who know the Yucatecan jungle, for it implies a fundamental misconception of the entire situation. The poor botanist may feel himself confronted with a psychologic problem in adult education, rather than with the accumu-

lation of new botanic data. At times, the not undangerous policy may have been followed of hiring men of various professional categories to agree with previously decided opinions, and to work on specific short-time objectives, sometimes for specific pre-determined results. In such instances, when results begin to appear negative, or even before, interest may be lost, the work stopped, often the records may be lost. Such a policy favors sterile repetition, with regularly repeated still sterile failures, coupled with unwarranted negative conclusions. In summary, we can say that "basic research", in the sense that we have used the phrase in this paper, is still undeveloped, as evidenced by existing publications. What work has been done in this category, as by Karling, can largely be placed at the hands of basic-research minded botanists who have effected them despite, rather than because of, the encouragement of industry.

This retrospect over the past quarter century by no means warrants criticism or adverse comment. It is presented here as a record and interpretation of historical fact. It represents an extremely interesting and normal period of an industry which is based on the exploitation of a natural resource. It bears curious and instructive parallels to such developments as have already been experienced by the rubber industry, by timber forestry, by the cattle-range industry and many others, all now well buttressed by stable research programs. It appears to me a perfectly normal chapter, analogous to what in other industries has been a normal growth. The final story—one facet among many in the history of American industrial research—remains for the future to unfold.

Potential Chicle Research

With the conspectus that has been presented, the phytologist can indeed wax enthusiastic about the research future of the chicle industry. Evolutionary trends can not be thwarted, even in the field of human economics, and it is only natural to expect that the chicle industry will some day enter another stage, following in the footsteps of rubber, sugar, pineapple, citrus fruits, bananas, hemp and many others. Even the development of a synthetic substitute need occasion no great pessimism, if we are to be influenced by the still great importance of natural rubber beside its synthetic substitutes.

To merely list the possible fields of research on chicle trees would be beyond the scope of this paper. It is easier to state that as a research subject, the field is essentially virgin. What we do not know is astounding. We do not have sufficient data by which to gauge height and diameter growth rates, the age of tappable trees, the age at which tapping is first possible, or the ecologic requirements for maximum growth. We know almost nothing of the forest itself, and of the rôle of the sapodilla in it. To assume that a plantation industry is impossible is as premature as to have assumed the same thing for rubber at a comparable stage in rubber history. And finally, numerous other species around the world give usable latex. We know even less about these plants than we do about sapodilla. What specific facts and techniques will eventually be extracted from the mass of future research-acquired data, to mold the industry of tomorrow, no one now knows. We who sit on the side lines can look forward to an unfolding and eventful panorama in the long history of man's utilization of the world's plants.

Plantation Rubber in the New World

The exigencies of the recent war induced the establishment of rubber plantations in the New World, of which there may now be 30,000 acres in the Island of Haiti, Mexico, Central America and northern South America.

W. N. BANGHAM[1]

Plant Sources of Commercial Rubber

ALTHOUGH rubber is elaborated, to some extent at least, by about 1,500 species of plants, few of these species form a sufficient quantity or a satisfactory quality of it to have achieved value as commercial rubber producers. In general, the rubber that is present within the specialized cells or latex systems of most of those species is so intermixed with resins, gums or other materials as to render extraction of it in reasonably pure form very difficult. Of the plants from which rubber can be obtained by destroying and disintegrating the plant source itself, only guayule (*Parthenium argentatum* A. Gray), a shrub native to the arid areas of the southwestern United States and northern Mexico, has attained importance. Among those which yield a rubber-containing latex and which therefore need not be destroyed and disintegrated, are a few trees and vines native to Africa and southern Asia (*Funtumia elastica* (Preuss.) Stapf., *Landolphia* sps., *Cryptostegia* sps. and *Ficus elastica* Roxb., chiefly). They attained some importance when rubber was available only from native jungle sources or when the flow of it was diminished by restrictions on commerce, by war or by governmental decree. None of them, however, has been a satisfactory plantation source of the material.

In the earliest contacts that European visitors had with the natives of the Americas they found rubber used in balls and as a waterproofing cover for cloth. Much of this rubber is supposed to have come from *Castilla elastica* Cerv. trees which were native to the regions first visited. This species has been planted in plantations at various times since then but has not given satisfactory sustained production. *Manihot Glaziovii* Müll.-Arg., a tree native to dry regions in Brazil, was also planted in a few early tests, and a considerable commercial planting of improved selections of guayule has been made in the southwestern United States. All these sources, together with wild *Hevea* of the Amazon Valley, accounted for approximately only two per cent of the total world rubber production in the years immediately preceding the war. It was the cultivated plantations of *Hevea brasiliensis* Müll.-Arg. which had become, by all odds, the dominant sources contributing to the world rubber production which before the war amounted to 1,500,000 tons each year, with a value of $756,000,000 at the fixed buying price of the United States during 1941.

Tapajos Jungle Provided Planting Stock for Oriental Rubber Plantations Free from Leaf Disease

Unique in the history of major world crops is our information about the origin of the planting material for the approximately 9,000,000 acres which have been

[1] Editor, La Hacienda; formerly Director, Plant Research Department, The Goodyear Rubber Plantations Company, Akron, Ohio.

planted with *Hevea* throughout the tropical regions of the world. This entire area, with a few minor exceptions, was planted with the progeny of one collection of 70,000 seeds, of which only some 2,800 germinated and survived. It is quite possible that some of the trees from which Henry Wickham (later to become Sir Henry Wickham, in recognition of his contribution to Empire Agriculture) collected these seeds in 1876 still stand on the plateau area 500 feet above the banks of the Tapajos River in Brazil, where he gathered them, and that some may still contribute to the native rubber production of the Amazon basin.

Only the genes which were present in this population from a very restricted location have been available to later breeders who worked on the plantations of Sumatra, Java and Malaya in their attempts to increase yields and to better adapt *Hevea* trees to plantation culture. The *Hevea* trees which grew in scattered distribution on the high banks of the Tapajos River, where there is a long and distinct dry period often accompanied by strong winds at the period of leaf change (wintering), rarely were severely damaged by the principal *Hevea* disease, South American leaf-blight, caused by the fungus *Dothidella ulei*. The population of *Hevea* trees in this area had not then been subject to natural selection strong enough to build into it a satisfactory amount of resistance to this disease to protect the trees when they were planted at plantation density in areas in which the environment was less favorable than that of their native plateau. Fortunately, however, for the industry which later developed from this collection of seeds, Wickham did not carry with him on the seeds viable spores of the blight. If he did include some they were lost during the journey or during the period in which the seedlings were maintained in the greenhouses of Kew Gardens. The seedlings thus did not carry the disease to the plantations which were established with them in Ceylon, Malaya and Java, and drastic control of the export of planting material of *Hevea* subsequently maintained by South American countries prevented transfer of the disease to the major plantation areas of the world with later collections of *Hevea*. The disease, therefore, was not introduced into the Orient, and the plantation areas of the East and the search for planting materials with superior ability to produce high yields was not hampered by the necessity to also develop resistance to this serious leaf blight.

Native Leaf Disease Prevented Use of Hevea on New World Plantations and Induced Attempts with Other Species

The freedom of Oriental plantations from the blight was not duplicated in New World plantings in regions in which *Hevea* was native. Only in limited areas which were favored with unusually fortunate climatic conditions did attempts to establish *Hevea* on plantations in Trinidad, the Guianas or the Amazon Valley result in mature and producing trees. Usually, however, these efforts ended in disaster after the South American leaf-blight successively destroyed all or most of the leaves of each new flush that appeared in the course of a few years.

During periods of high rubber prices a great expenditure of capital of American, European and of local origin was invested in Mexico, Central America and South America to establish rubber plantations. After the risks connected with planting *Hevea* became well publicized, most of the plantations were planted with *Castilla* trees, but production from these trees was low, under the severe tapping practices in current use. The plantations rarely survived long in the hands of the original owners, after the plantations of *Hevea* in Ceylon and

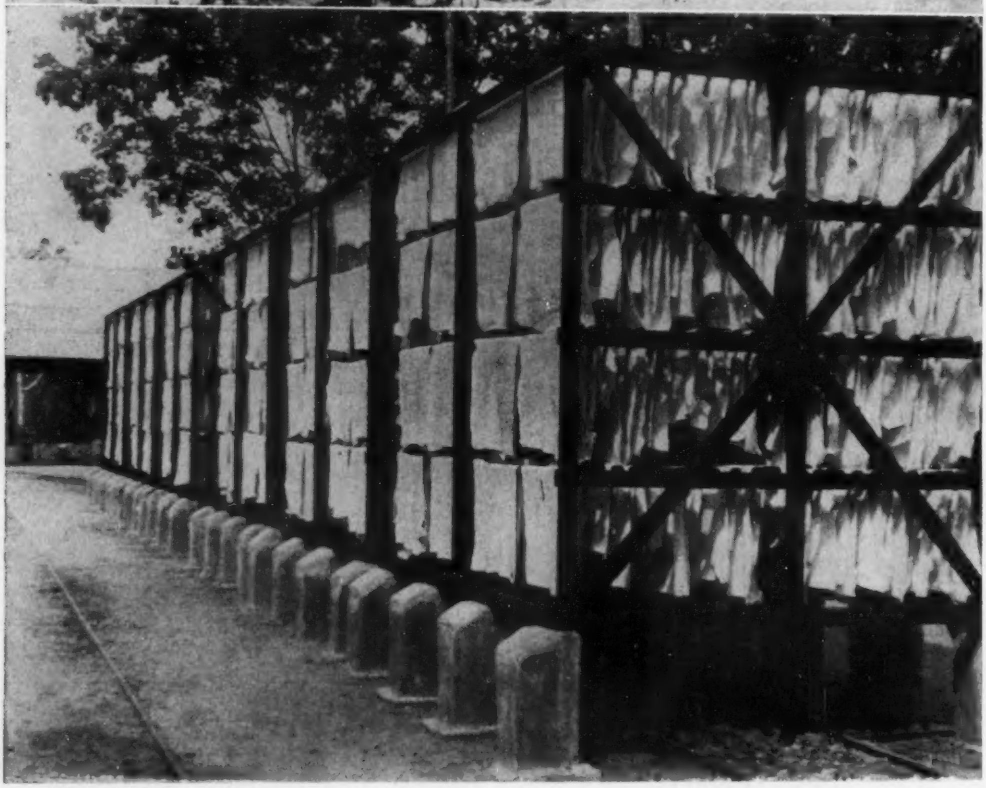

FIG. 1. (*Upper*). Extensive nurseries, as pictured here on the Goodyear Rubber Plantations Company Wingfoot Estate in Sumatra, were required for large-scale planting operations.

FIG. 2. (*Lower*). A few laborers in the processing factories of modern estates prepare clean, uniform sheets of rubber from the latex collections of many tappers, as pictured here on the same estate in Sumatra.

Malaya started production on a large scale. The total loss of investment which the investors suffered in these American plantations gave rubber as a plantation crop in the American tropical areas a permanent shock, from which it has not recovered.

When *Castilla* plantations failed because production costs were high and the quality of the rubber was low in comparison with that of *Hevea*, many of the trees survived among the competitive jungle growth which came up among them. These survivors served as the source of much of the *Castilla* rubber which helped so vitally in the production of war materials during the recent war. Although there does not appear to be any need to consider *Castilla* as a plantation tree in the immediate future, there is justification for some protection of this tree in jungle areas, for its value as an emergency source of rubber.

Guayule rubber was adapted to plantation culture largely through the efforts of Dr. David Spence and his staff in the laboratories of the Inter-Continental Rubber Co. at Salinas, California. This group, which has recently had the help of governmental and University agencies, has improved rubber yields, decreased resin content and developed cultural, harvesting and processing machinery. Even with the remarkable improvements which were made in the plants and the substitution of machines for human labor in handling, the crops have not yet reduced production costs to a point which will permit guayule to compete with improved *Hevea* on a direct cost basis. The rubber from guayule is said to be particularly well adapted to use in certain mixtures with synthetics, and it may find a place permanently in the agriculture of certain arid areas, but it appears improbable that it will in the near future supply a larger percentage of the plantation rubber than it does at this time.

No other species of plant has threatened the dominating position of *Hevea brasiliensis* in rubber production, or appears likely to do so. It is possible that synthetic materials will continue to replace some rubber in tires and other products which utilize large volumes. The extent of this substitution will depend chiefly on the legislation which will determine the national policy with respect to the synthetic factories. Despite the low price at which it was estimated that synthetic could be made with the most modern methods (one estimate was between 13 and 15 cents per pound), the former plantations of improved *Hevea*, with unrestricted export, could operate at a profit in years prior to the war. It is impossible to determine either the potential quantity or cost of rubber which will come from the plantation areas of Indonesia and Malaya after this period of social unrest resolves itself. It is very certain that wages will increase and that labor productivity will be lowered in that area. These changes will lower the differential between the cost of producing rubber in the East and the same costs in the Americas.

Most Eastern Plantations Are Planted with Low-Yielding Hevea

Approximately 90% of the plantation areas of *Hevea* in the Orient, including native-planted areas, are planted with a random mixture of seedling progeny from the original Wickham trees. This type of planting material has produced an annual yield of 450 to 500 pounds of dry rubber per acre per year on large European plantations, and somewhat more than that on the thickly planted native holdings. Mr. H. N. Whitford, of the Rubber Manufacturer's Association, found the native tappers to bring in from their own holdings about eight pounds of dry rubber for each day of tapping, and these men usually used a part of the day to process their product.

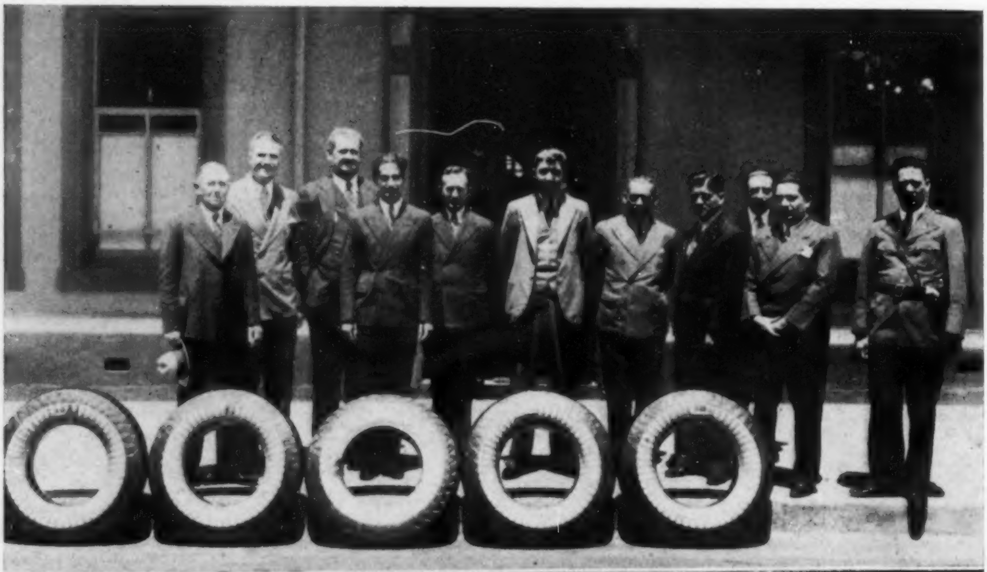

FIG. 3. (*Upper*). The President of Costa Rica receiving the first tires made completely from plantation rubber raised in the New World.

FIG. 4. (*Lower*). Messrs. J. J. Blandin, P. W. Litchfield and A. G. Cameron examining the first sheet rubber from the Goodyear Rubber Plantation in Costa Rica.

Careful control, on the other hand, of tapping procedure and of tapping panel diseases has permitted tappers on European-operated estates to collect from 18 to 20 pounds of dry rubber from each day's tapping, from similar unselected trees. On the estates one man in the factory could process the product of ten or more tappers each day.

The remaining 10% of the plantations in the East, all European or American owned, were planted with trees that originated in an extensive breeding and selection program. Perhaps 20,000,000 seedling trees had their yields recorded for a period of a year or more to select the superior trees. Progenies of these were propagated by budding. Yield tests of the progenies gave an indication of the value of the clones for larger scale trials.

By generative crosses among the best seedlings discovered within the natural stands, production was increased to levels above that of natural populations. The mean yield of a population from the superior parents frequently was equal to that of the parents, indicating that the mean had been increased by selection and one generation of crossing to a level approximately three times the mean of the population from which the parents had been chosen. Few of the combinations or re-combinations involving more than two generations of crossing within this selected body of material had been tapped before research stopped in the Indonesian and Malayan areas with the arrival of Jap invaders. Since improvement was so rapid in these first generations, it appears reasonable to assume that improvement of the *Hevea* tree has not reached the maximum ceiling for yields. We anxiously await information as to the yields of advanced generations, which should be mature when the Indies are re-opened.

In addition to providing an increase in the yield-potential of the trees, the selection program eliminated, when possible, those clones which were unduly susceptible to a breakdown of the latex vessels (brownbast), to severe wind damage and to uneven renewal of bark on the tapped panels, and also eliminated trees with a branching habit which would not stand the competition of planting in stands of mixed clones.

The best of the clones which originated from selections of outstanding trees in natural seedling populations gave commercial yields on a large scale that was about three times that of the population from which it was selected, or about 1,500 pounds per acre per year. The best of the clones resulting from controlled crosses has given 2,000 pounds from large plots. Tappers working in tasks of such trees bring to the collecting station the equivalent of 40 to 60 pounds of rubber per day. With a minimum of 300 tapping days, a tapper working with this class of *Hevea* can get an annual yield of 12,000 pounds of rubber.

Jungle Rubber Gives Meagre Return from Land or Labor

How does this return compare with that of the Indian who hunts his rubber from wild trees? The Rubber Development Corporation has made an extensive check of the annual crop of rubber tappers in South America during the war years, and has reported that the yields vary from a low of 440 pounds in the Iquitos area of Peru to 1,760 pounds in the Rio Beni area of Bolivia. The data on the page following indicate the comparative yields of the various tappers and their annual crop values at the 1941 world price of $0.225.

The relative advantage of the estate laborer is reduced by reason of the capital required to prepare the plantation for him to tap, and by the upkeep and factory labor which assist him in processing rubber from the latex that he collects. When we discount these factors we still

ANNUAL RUBBER CROP PER TAPPER

Tapper	Type of Tree	Yield (pounds dry)			Value ($ USA)
		Per Tree	Per Acre	Per Tapper	
Native Iquitos	Wild	2	—	440	$ 99.00
Native Rio Beni	Wild	?	—	1760	396.00
Sumatra native	Unselected	5	600	2400	540.00
Sumatra estate labor	Unselected	6	450	5400	1215.00
Sumatra estate labor	Best clones	15	1500	12000	2700.00

find that the tapper working with improved clones in an estate has a very marked superiority in his annual crop as compared with the native in the jungle or the native small-holder in Sumatra, who taps relatively low-yielding trees.

It is not necessary for prospective plantations in the Americas to pass through the same stages of economic development as do those of the Indonesian natives, with their available land planted to rubber on a low productive level. High-yielding clones can be planted here, and the American plantations will have the advantage of production levels equivalent of those of the top 10% of the industry in the East. The Inter-American Economic and Social Council of the Pan-American Union reported that 69,185 laborers were occupied in the collection of rubber from wild sources in South America during 1944. Even in times of extremely low prices many of these tappers continue to exploit rubber. Would it not be good economy to aid them to plant improved rubber trees near their homes and to get the advantages of this greatly increased efficiency of labor and land use? We cannot explain the production of rubber by the Amazon natives on the basis of an attractive return, but if they are attached so tenaciously to their localities, it is possible with planted rubber to bring them a more fruitful life in their customary occupation.

Not only do the laborers in the wild rubber areas obtain a small return for their effort, but they are subjected to very unhealthful conditions, a lack of medical facilities and a very high mortality. Poor temporary shacks provide shelter, food is often scarce and poor in quality, and medical services cannot reach remote locations. With a single hectare of the best available clones, top-budded with a resistant clone, the tapper could live and work within sight of his home and still obtain as much as seven times the rubber that he now gets from a year's work.

Concentration of rubber production into small units of planted area will make it possible for the rubber tappers to live in more comfortable permanent houses, where an adequate supply of food and medical services will be possible. Despite the advantages to be gained from having planted rubber replace the wild, the impetus to make this change will not come from the tappers themselves, at least not until they can see in their region producing units on the scale of their potential holdings. If these units are established by a local governmental agency they will encourage the spread of this type of planting.

Production Restrictions Bring Rubber Back Home

Despite earlier failures to establish a rubber plantation industry in the Americas, development of these plantations obtained new impetus from the promulgation of the "Stevenson Scheme" to restrict export of rubber from the chief producing areas within the British Empire. The Ford Motor Company purchased a concession of about 2,500,000 acres along the Tapajos River in Brazil, in which it planned to exploit timber and jungle products and later to plant the deforested area with plantation rubber.

The United Fruit Company imported some seed from selected high-yielding "Mother Trees" from the estates of the United States Rubber Company in Sumatra. This company started small rubber plantations on land in Costa Rica, Honduras and Panama, which had no further utility for growing bananas, after the soil had become infected with Panama Disease (*Fusarium cubense*).

The Ford attempt to exploit the Amazonian timber and other jungle products was ill-timed. Depression economy which dominated world trade at the time they were ready for market did not permit profitable introduction of the new products. Wood-working machinery could not cope with many of the extremely hard woods, kiln-drying procedures were unknown for many of them, and it was very difficult to obtain considerable quantities of timber that would behave in the same manner as did a sample. Young planted rubber from local seed succumbed to attacks of South American leaf blight, and insect pests which were unknown as enemies of *Hevea* in the wild, became devastating. The company was forced to abandon plans of large-scale expansion of rubber planting until it can obtain a satisfactory control of some of these plagues.

Only a small portion of the planted area of the United Fruit Company *Hevea* was of the improved material. When the Stevenson Scheme failed and rubber prices again dropped, this company realized that the low yields which could be obtained from unimproved trees could not support profitable operation. The company abandoned its plantations in Panama and Costa Rica, at which time they were apparently healthy. However, when the author arrived in 1935 with Mr. B. E. Bookout, Agricultural Superintendent of the United Fruit Co., remaining trees were heavily defoliated by *Dothidella ulei*. There is still no record of the trail by which the disease reached Panama and Costa Rica. This plantation in Costa Rica was later purchased by the Goodyear Rubber Plantations Company and became the base for their studies of control methods for South American leaf blight.

The Goodyear Rubber Plantations Co. had established a plantation on the island of Mindanao, in the Philippine Islands, in 1928 as a first step towards eventual planting in the Americas. The better clones from all sources were established there as soon as they were available. When, in 1934, the International Rubber Restriction Agreement limited the export of rubber from all the major producing centers of the world, the agreement also prohibited movement of rubber-producing plants out of the countries within the agreement. The Philippine Islands had not joined the agreement, and the Goodyear collection of clones was the largest outside the restricted area. Impending conflict in the Pacific area, the danger of having the entire source of their chief raw material come from a small portion of the globe, and the danger inherent in having this material controlled by a producer's association, were factors which were influential in a consideration of the possibilities of plantation-scale production of rubber in the American tropics. High yields that could be obtained from the clones which the company had on the Philippine estate should off-set the wage differential between the American tropics and the plantation areas of the East where the majority of rubber production was from low-yielding trees.

Leaf Disease Control Essential for Permanent Plantations in the New World

A shipment of plants of 1,100 clones to a new estate established on the borders of Gatun Lake in Panama was to be the base for distribution of planting material, and commercial production was

planned for an estate in Costa Rica. The discovery that South American leaf blight had arrived in Costa Rica before we did had a destructive effect on plans for the immediate building of a plantation for commercial production. A program leading to control of this fungus became immediately essential if plantations were to hope for successful survival at any point in the hemisphere.

A survey trip to Trinidad, the Guianas—where Stahel had for many years studied this disease—and to the Ford plantations in Brazil, brought little encouragement of attempts at control of the fungus with fungicides. Favorable climatic factors in the Tapajos area had permitted eastern clones, which the Ford Plantations had imported before the Restriction Agreement had discontinued access to them, to make some growth in spite of seasonal damage. Dr. J. R. Weir had attempted to offset this damage by budding at about six feet above the ground with buds of *Hevea guianensis* Aubl., and from them to obtain crowns with some resistance to the disease. This procedure worked well in favorable climate where the eastern clones could reach a height for top-budding with little damage by the disease. It was not the answer to our problems in Costa Rica and Panama, however, where the disease stopped growth of the trees and reduced their vigor long before they were large enough to be given a resistant crown. The Ford staff had made another observation which had outstanding value to our program and which gave us the courage to proceed with our battle against the fungus. They had found that a seedling population collected from the frequently inundated islands near the mouth of the Amazon, and also a population collected from some of the cloud-bathed foot-hills of the Andes along the Acre River, had mean resistance levels to the disease which appeared to be higher than the extreme resistance exhibited among the Tapajos seedlings. Since the Tapajos population was the basic stock of our plantations and of the improved clones, it became necessary to return to the Amazon for the genes that would give our trees the resistance to protect them from the disease.

Permanent Plantations Require High Yields Too

The resistant populations were very low in their yield levels. That from the region at the mouth of the Amazon was later found to average only half of the yields of the unselected Tapajos seedlings. Obviously a plantation could not compete with high-yielding Indonesian estates when planted with such material any better than could plantations of clones without resistance to the disease. The staff of the Ford Estates utilized the climatic advantage which permitted them to grow the eastern clones to flowering size and intercrossed these clones with the resistant trees. Some seedling families with a very high level of resistance resulted from these crosses. Early yield tests of the seedlings promise that the eventual planting materials for plantations of *Hevea* in the Americas will have their origin among these crosses or those which were later prepared by Mr. L. A. Berry, Jr., who worked at the Ford Estates on a program cooperatively supported by the United States Department of Agriculture and the Instituto Agronomico do Norte of Belem-Para, Brazil.

When the war emergency placed the rubber plantation areas of the world in jeopardy, funds were appropriated to the United States Department of Agriculture to assist the development of a rubber plantation industry for our hemisphere. First, a survey of areas suitable for rubber growing was made, and cooperative agreements were reached with many of the American Republics, which insured a free interchange of improved planting materials and of information.

FIG. 5. (*Upper left*). Scaffolding erected to permit access to the flowers of high-yielding *Hevea* clones and thus to facilitate the making of cross-pollinations with pollen from high-yielding strains. This procedure carries the hope of combining satisfactory levels of yield and resistance in the same tree, and averts many budding and spraying operations.

FIG. 6. (*Upper right*). Hevea trees are tapped near the ground and climbing them is not necessary. A tapper can tap 400 or more trees per day on plantations.

FIG. 7. (*Lower left*). Tapping castilla trees requires strength and skill, and few can be tapped by one man in a day's work.

FIG. 8. (*Lower right*). A blight-resistant scion grafted on a high-yielding but blight-susceptible stock. The scion will develop a crown with healthy foliage for the latex-producing trunk which, in turn, has been grafted on a good rooting stock.

These have been of essential value to subsequent development of the plantation industry.

Before facilities for research were available the U.S.D.A. sent Dr. M. J. Langford to the Goodyear All-Weather Plantation in Panama. There he developed a spray procedure which gave very satisfactory control of the disease in nursery areas. Later, at Turrialba, Costa

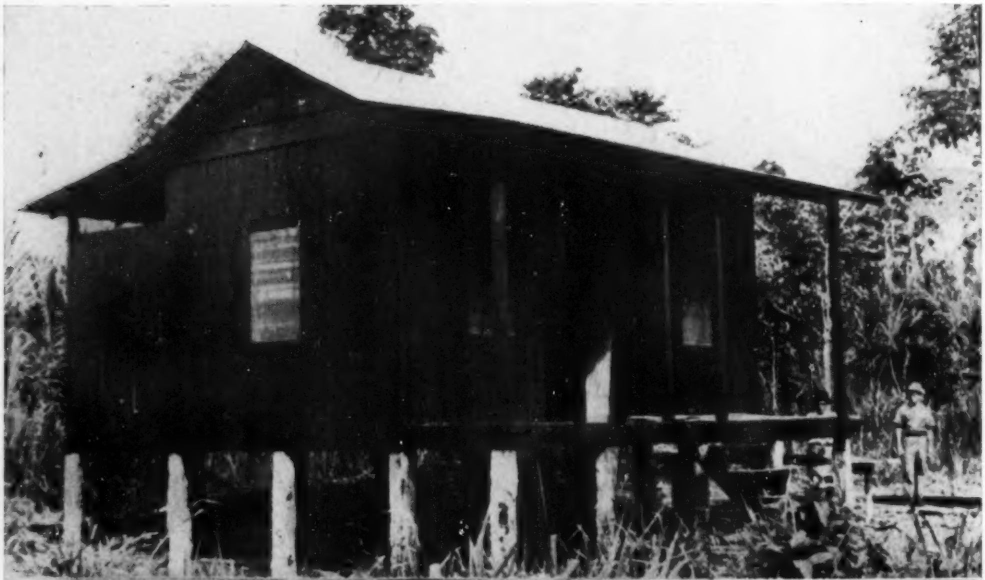

FIG. 9. (*Upper*). A screened house provided for laborers on a plantation is much superior to the primitive dwellings of tappers in jungle areas.

FIG. 10. (*Lower*). A native in the rubber country of Brazil coagulating rubber in successive coatings on the end of a stick by repeatedly dipping the stick into a mass of collected latex and then rotating it in the smoke of a fire.

Rica, he adapted his equipment and procedure to give equally effective control of the disease on non-resistant trees which were planted at field spacing. This practice has become the keystone of the entire program of disease control. It made it possible in all climatic zones to protect the non-resistant high-yielding eastern

clones until they can be given a crown of resistant origin.

Dr. E. W. Brandes and Dr. R. D. Rands, at the Beltsville headquarters of the Bureau of Plant Industry (U.S.D.A.), and the staff of the Central Experimental Station at Turrialba, Costa Rica, under the direction of Dr. Ernest Imle, have maintained constant contact with the accomplishments and the needs of the research workers in each of the cooperating government and industrial groups. They cared for the distribution of scarce planting materials and technical assistance among the projects, and formed the clearing-house for information that originated at any point in the program.

War Emergency Leaves Hevea Plantations in Many New World Countries

Unfortunate as it was that the essential investigation had not been done before the emergency arose, the end of the war in the Pacific (and of the emergency) found the plantation culture of rubber firmly established in many republics of Tropical America. Dr. E. W. Brandes included in the introductory comments of the U.S.D.A. publication, "Cooperative Inter-American Plantation Rubber Development", the following table showing the extent of new plantation rubber at the end of 1945:

SUMMARY OF HEVEA PLANTINGS BASED ON INCOMPLETE REPORTS FROM COOPERATORS

Country	*Estimated acerage at end of 1945*
Brazil	16,000
Colombia	510
Costa Rica	2,400
Dominican Republic	30
Ecuador	....
El Salvador	....
Guatemala	1,129
Haiti	6,500
Honduras	813
Mexico	347
Nicaragua	125
Panama	125
Peru	68
	28,047

Reports from which the above table was compiled apparently did not always include rubber which had been planted in colonization projects or other small holdings. These were at times supervised by local government technical men and were in part financed by the government as a portion of the expense of setting up the projects. On page 70 of the report, "Caucho" (Rubber), of the Consejo Inter-americano Economico y Social (Inter-American Economic and Social Council) of the Pan-American Union, dated September, 1946, there is the following statement (translation—W.N.B.):

"At this date there have been planted 3,750 acres of Hevea rubber in Mexico, and it is expected that the number of planters, that is now about 650, will increase to more than 1,000 during the coming rainy season. Now the valley of el Palmar, Veracruz and the area of Tabasco Chiapas, in the south of Mexico, are the regions where rubber is being planted".

Mexico has the most active locally financed program of assistance to the small holders of rubber plantings that has yet been established in the Americas. It is the expressed aim of the agricultural authorities of that country to produce enough *Hevea* rubber in Mexico to meet the needs of their rapidly developing rubber manufacturing industry. They wish to protect their transportation facilities from future shortages of tires if a new emergency interferes with supplies. This report ("Caucho") also refers to the *Hevea* rubber planted in Haiti. The plantings there were largely made by the Sociedad Haitiano-Americana de Fomento Agricola (SHADA) as a contribution to our emergency supplies. It is reported that considerable portions of the area originally planted have been abandoned and that the areas which are being maintained amount to between 1,400 and 1,600 acres.

In Brazil *Hevea* plantations consist chiefly of the former plantations of the Ford Motor Company, which were sold

to the Brazilian government after the Ford Company ceased to manufacture tires and no longer needed a source of raw rubber for its factory operations. The plantations were largely made up of high-yielding eastern clones which had already been top-budded with resistant tops. Production has started on the estates, which contain a tremendous amount of valuable breeding stock from eastern sources and from all parts of the Amazon Valley. The plantations are being administered for the Brazilian government by Dr. Felisberto de Camargo, who also is Director of the Instituto Agronomico do Norte, at Belem. It is certain that under his direction the collection of planting material will be developed and will produce much valuable planting material for the plantations of the future.

Colombia has financed nurseries and some extension of *Hevea* planting in connection with a colonization program. Peru, Nicaragua, Guatemala and Costa Rica maintain cooperative experiment stations in which propagating material of the high-yielding clones from the East and clones for top-budding with tested resistance are available. In some cases plants and budwood from these nurseries are given to the planters who wish to establish small areas of rubber. Elsewhere they are sold at a nominal cost.

The United Fruit Company has planted high-yielding and top-budded *Hevea* on a plantation scale in Honduras, Guatemala and Costa Rica, within its program to substitute new cultures for bananas on land which will no longer serve for that crop.

Planting has been completed and experimental-scale production has begun on the 2,500 acre plantation of the Goodyear Rubber Plantations Company, at Cairo, Costa Rica. Results of a tapping test made on young top-budded trees of about 20 clones were closely comparable to the yields from the same clones when they had their own tops and were first tapped in Sumatra. Although the top used for top-budding had a very low potential yield, it apparently had little influence on the ability of the tissues within the cortex of the trunk to elaborate latex. Similar results were obtained from tapping tests conducted at the Ford Plantations in Brazil and among the few trees which have been tapped on the plantation of the Interamerican Institute of Agricultural Sciences, in Panama.

Local Manufacturers Provide Best Market for New World Plantations

The plantations which have been established in various countries of the New World have a potential productive capacity roughly equivalent to the entire output of rubber in this hemisphere during pre-war years, but they do not increase the probable export of raw rubber that is to be expected from this region. New rubber factories, which at present manufacture the most popular sizes of tires and varied mechanical goods, have been built in several of the rubber-producing countries. The demand of these factories for rubber will often increase faster than will production from the plantations which have so far been established. Increased accessibility of formerly remote areas has been brought about by increased demand for agricultural production, by construction of improved roads and by the availability of "Jeeps" which can negotiate roads that were formerly passable only for burros and ox-carts. Even the stand-by of transport into wild areas, the ox-cart, has been transformed and rides on rubber instead of rumbling along on steel-rimmed wooden wheels. The demand for rubber tires for these carts knew no bounds when it was demonstrated that a yoke of oxen could haul double the quantity at a faster pace on rubber tires, when they replaced the narrow steel-

FIG. 11. (*Upper left*). Dr. M. J. Langford (right) pointing out to Mr. J. J. Blandin, Dr. R. D. Rands and the author, the superior resistance of one clone from a jungle selection.

FIG. 12. (*Upper right*). A seedling of *Hevea brasiliensis* budded with a bud from a high-yielding clone being removed from the nursery bed for transference to the field planting.

FIG. 13. (*Lower left*). Nurseries of root-stocks or of non-resistant budwood can be protected from South American leaf-blight if properly sprayed.

FIG. 14. (*Lower right*). All-weather roads are important features in high-yielding plantations, for tappers can not carry the latex from a day's task in such areas when the trees are mature.

rimmed wheels. As in the rest of the world, new uses are found for rubber each year here in its native home. Production that was formerly sufficient no longer suffices. The new plantation areas will insure that a supply will always be at hand, and if this is insufficient for the growing local demand it will nevertheless be a powerful stimulus to the planting of new rubber areas.

Small Farms Will Provide Much of the American Rubber Production

It is improbable that we are to see the development of much of the rubber industry in the American Republics take the form of large corporate-owned areas, as were the chief production units in other regions. The social structure of many countries of the Americas, their relatively small populations, the popu-

larity of labor legislation and the love of land ownership on the part of the laborers, all oppose the establishment of this type of productive unit. Rubber production, to adjust itself to the permanent economy of these countries, will have to come from small family-size production units. Such small-scale production units began their development in Malaya and Indonesia after rubber had been established as a plantation crop in those areas. Production from the small areas has constantly grown at a higher rate than has plantation production, and it appears probable that, with the exception of latex and other products requiring the attention of a chemist or technical man during processing, it will be small farms which will produce most of the world rubber of the future.

Rubber as a crop has many attractive features for the owner of a small plot of land, in the areas where it can be grown. When the trees are mature a crop can be harvested at any time of year and can be converted into cash within one or two weeks. The product has a high value per pound, it can be stored without serious deterioration, market grades are easily determined, and the price is clearly established by the world market. Trees can be tapped intensively to give greatly increased yields when there is a sudden need for income, or the trees need not be tapped and will not suffer if other work demands one's time. Loss of a crop as a result of sudden showers wipes out only the labor of a single day, and does not destroy the work of a season, as bad weather during the harvest of a crop of beans or rice may do. When the trees are mature they require little care, and with reasonable caution during tapping operations will continue to yield rubber for 25 years or more.

Two factors, aside from the normal inertia and conservatism of agriculturists the world over, are chiefly responsible for the slow acceptance of rubber as a crop among the small farmers of the Americas. The lack of capital to support the clearing of land, the purchase of planting material, and the upkeep of the trees through five unproductive years is first apparent. This problem was met by the Indonesian planters through the use of food crops planted among the young rubber trees until the latter shaded the ground and could battle the undergrowth alone. In a series of experiments on the estates of the Goodyear Rubber Plantations Co., in Costa Rica, we learned that inter-crops among young rubber trees do not give as serious competition with the growth of the trees as do native plants. Planting, top-budding and growth were all considerably improved in areas which were cultivated with inter-crops.

Planting and Budding Technique

The native planter interested in rubber cultivation will find the chief drawback connected with this crop, at the present time, is that he is incapable of following through the many complicated horticultural practices that are now required to get a resistant and high-yielding *Hevea* tree planted in his property. A nursery, preferably planted with seeds from a resistant population, containing from four to eight seedlings for each tree that it is ultimately desired to plant, must be established a year or more before planting begins. At the same time, a few stumps budded with high-yielding clones are planted to provide multiplication of budwood. These must be frequently treated with fungicidal spray, if the area is one in which disease is present. When the seedlings are about one-half inch or more in diameter they are budded at a point about four inches from the ground with buds from the multiplication area of high-yielding clones, and the top of the seedling is cut off to force growth from these buds. The shoot which develops must be protected with spray until

it has brown bark on about six feet of the trunk. A bud of a tested resistant clone, known to have a high growth rate and a low rate of wind breakage (when used as a crown), is then budded into the top of the high-yielding trunks at a point about six feet above the ground. The top of the trunk is removed to force growth from the resistant bud, and if weather is perfect (moist–dull) for planting, the budded stumps can be taken to the field areas for planting. For more security the trees should remain in the nursery until there is approximately two feet of brown wood on the resistant shoot. The tree is now two years old, heavy, and presents a problem of needing large planting holes, careful planting procedure and good weather to insure a full stand.

Competent horticulturists have a difficult time planning the above procedure to supply the necessary quantity of planting material when the weather is suitable and the land cleared for planting. The man who contemplates beginning his rubber planting with 500 trees or less is completely baffled. Usually he will not plant a new crop unless he can get the trees in a condition in which they can survive with the minimum amount of care.

Plant Breeders Must Combine High Yields and Resistance to Encourage Small-Farm Planting

When we obtain from the new crosses between Eastern and Amazonian selections, some clones which combine yield and resistance to a satisfactory degree to give us planting material which will produce 1,500 pounds of dry rubber each year, and which will not need to be sprayed or top-budded, we can hope to see a small-farm native rubber planting of considerable proportions develop in the most suitable areas of the Americas. Until such material is ready for distribution small areas will be planted with rubber only in countries which distribute planting material that is already top-budded, or supervisory and technical service which constantly checks to see that spraying and budding are done at the proper time and with correct materials.

The small-scale planter can process his


FIG. 15. (*Left*). The partially defoliated appearance of a young rubber tree infested with the South American leaf-blight disease.

FIG. 16. (*Right*). Corn which has been improved by inbreeding and hybridizing makes a profitable inter-crop for young rubber plantations.

rubber into smoked sheets and make a product that answers the requirements for the major uses of rubber with cheap and simple equipment. It is necessary for him only to get the latex to the coagulating tanks or pans without incipient coagulation, to strain the latex several times, to settle out particles of sand, and to use a uniform amount of acid for coagulation; all this to turn out a quality of rubber equal to that made with the best processing machinery and acceptable in the market at top prices.

We have discussed the advantages of rubber for the man who plants from one to five hectares of rubber which he can care for and tap with the members of his family. He has no need to consider the charges for hospitalization, overtime, vacation or dismissal pay that social legislation requires of those who hire labor. Can plantations compete with him? We can answer only that they have always been able to do so in the rubber areas of Malaya and Indonesia, where the two were adjacent. This was made possible by the research which was maintained by the estates. They utilized labor-saving practices, improved planting materials, selective thinning, factory and transportation machinery and other means of lowering production costs. The owners of the small-scale units at no time developed any of these labor-saving practices and seldom borrowed the practices which were found effective on the estates beside them. This lag in the use of improved planting materials and practices on the part of the small farms gave the plantation operator a sufficient margin of efficiency to cover his costs for management and research with enough margin to frequently permit a profit. Important as research was to the estates in the Malayan region, it is essential to plantations which will be planted in the Americas. High labor costs, relative to former costs in the Malayan area, can be offset only by planting new plantations for the minimum capital outlay, planting them with material which will combine high yields with resistance, and by the use of only the most efficient production methods. Continuous research will be required to maintain an advantage that is gained over competitive areas, whether the competitors are adjoining small estates or large plantations in other places.

There is another reason to look forward to the maintenance of rubber production from a certain number of plantations of medium or large size. There has been a considerable increase in the number of uses for rubber during the past few years, and the Americas are more available to our factories than are other producing areas. Many of the new uses require that the rubber processing start almost as soon as the latex leaves the tapping cut. For example, in the preparation of liquid latex, an anti-coagulant is often added to the cup. Use of liquid latex, either in natural or concentrated form, for the preparation of latex-foam rubber for upholstery was one of the fastest-growing new uses of rubber before the war. The latex for this material must arrive at the manufactories without the slightest incipient coagulation. The clone, the tapping-system, the weather and the time of arrival of the latex at the processing center all affect the quality of the latex and the amount of anti-coagulant to be added. All factors must be as favorable as it is possible to get them to deliver a superior latex to the factory. Sufficiently close control to get this latex in satisfactory condition usually requires a well-staffed plantation organization with a chemist always checking procedure. The small-scale planter can not provide this care. Other products, such as rubber-sheets or latex with low-water absorption, soft rubber, crumb rubber and rubber suitable for the preparation of clear films for the prevention of humidity exchange in prod-

FIG. 17. Three-element Hevea trees in plantation. Below the bulge near the ground is a root of resistant stock. Between this lower bulge and the curved portion of the tree slightly above the head of the man is a trunk of a high-yielding, non-resistant clone. The top of the tree is of another clone which is resistant to the leaf-blight. (*Courtesy Dr. E. W. Brandes, U. S. Bureau of Plant Industry.*)

ucts ranging from delicate foods to airplane engines, all require the assistance of a technical staff in their preparation. Other products were being developed before all natural rubber was required for war equipment, and we can look forward to the appearance of many new uses of rubber when fresh latex is again available to our chemists.

In many of these uses synthetic materials have not been successful in replacing the natural product. It will still be necessary to have available a suitable quality of fresh latex of the necessary specifications if we are to continue to keep up with the new uses which have been found for some of these rubber articles. At the present time the plantations which are reopening in Malaya are again becoming the source of this latex for specialized products. Western Hemisphere sources have not yet achieved sufficient productive capacity to meet the demand from the production of these articles, and cannot do so until plantations are much larger than any which are so far established.

Will the demand for autonomy extend to Malaya? Will we continue to have a trade with that area in sufficient volume to permit the former low freight rates? Will the demand for increased wages in Malaya offset present low production costs? Will trade restrictions interfere with the free access to these areas, and will our technical workers be permitted freedom to work there? It is in the answers to these political and economic questions that lies the immediate future of the use of rubber in our newer products. In their solution we will be able to find the answer to our question, Is there a profitable future for rubber plantations in the Americas?

A greater amount of clairvoyance or skill in prophecy than is possessed by the author will be required to assure us that trade and production in Malaya will become re-instated on a basis that will permit uninterrupted supplies of these essential grades of rubber to reach us from that source. Renewed difficulty in getting supplies from that already-established source will become the basis of further interest in building an alternative source from plantations in the Americas.

Many Factors Favor Permanent Hevea Plantations in the Americas

We now know that it is possible to establish these plantations in the tropical portions of the Western Hemisphere and to obtain from the trees in them similar or even better growth and yields than we had in our best plantations in Indonesia or Malaya. Slight increases in planting costs will protect the trees during their lifetime from the principal disease of *Hevea*, caused by *Dothidella ulei*.

Productive life of trees planted in plantations of the Americas will probably be much longer than that of trees in the Eastern plantations, and the cost of maintaining the trees in a healthy condition will be considerably less here. For some reason that has not yet been discovered, the *Fomes* group of root diseases, which greatly shortened the producing life of rubber trees both in the Asiatic tropics and in Africa, has not damaged *Hevea* trees in the plantations of the Western Hemisphere to a serious extent. Other pathogens that were at times serious and difficult to control in the East, *e.g.*, *Corticium salmonicolor* (Pink Disease) and *Oidium* sp., do not appear to be as virulent in the tropical areas of this hemisphere.

The end of the war and of the emergency in the supplies of natural rubber from former sources finds us with a small but firmly established rubber-plantation industry in the tropical countries of the New World. Generally this new industry is in the hands of governmental or industrial agencies which are sufficiently well financed to insure that the areas will

be maintained until they are able to operate from profits. Expansion from this nucleus into a major new plantation industry for the Americas will without doubt await the solution of the political and social problems of the areas of Indonesia which contain a major portion of our former rubber-producing plantations. Growth of a demand for a reliable source of latex and rubber for new products, and of the requirements within Latin-America for a raw material for local rubber factories may be sufficiently rapid to force new planting in this area, even before the future economic status of raw rubber in the world's markets is fully established.

Rubber as a plantation crop for the Americas has been established and will remain.

Utilization Abstracts

Insecticide from Southern Pine Stumps. In 1940, one year before Pearl Harbor, the Hercules Powder Company announced the production of "Thanite," an insecticide made from southern pine stumps and named after the Greek word "thanatos" meaning "death." In chemical parlance Thanite is the isobornyl ester of thiocyanate, a terpene derivative obtained from stumps of pine trees as part of the wood naval stores industry. In this industry pine stumps, after being lifted, are shredded by machinery and then extracted to yield a wide variety of products, mainly rosin, pine oil and turpentine. It is from the last of these that Thanite is derived. The investigations which led to the discovery resulted from efforts to find among the derivatives of pine oil and turpentine, either an activator for the commonly used pyrethrum or a derivative which of itself would serve as an effective insecticide and render American industry independent of foreign sources of pyrethrum. Japan had long been the single large source of this spray material, imported into this country as an extract. The British Kenya Colonies in Africa were a secondary source. Involved in the research that led to this development were Kansas State College, University of Delaware, University of Florida, Rutgers University, Cornell University and scientists of the U. S. Department of Agriculture and of other insecticide manufacturers than the Hercules Powder Company. (*L. P. Killilea, Chemurgic Papers, 1946, Series No. 3, No. 450*).

Vegetable Oils in Soaps. In 1945 the American soap industry consumed more than two billion pounds of oils, fats and fatty oils. Of this amount, 250,000,000 pounds were derived from vegetable sources; the remainder from tallow, grease, fish and imported oils. Before the war the manufacturers of liquid or paste soaps (which cannot be molded into cakes but are shoveled out of a barrel and dissolved for use as a liquid out of dispensers) used principally imported coconut oil and potash as well as various other oils from foreign plant sources, *viz.*, tea seed, rubber seed, hemp seed and Japan wax. These bland oils were preferred because of their high lauric acid content providing the two ingredients "glyceryl laurate" and "glyceryl myristate" which give rich sudsing and quick lathering properties. Cohune nuts [*Orbignya Cohune*] from Mexico and Honduras, babassu nuts [*Orbignya speciosa*] and murumura nuts [*Astrocaryum Murumura*] from Brazil provide similar oils.

The great need for these bland oils could possibly be better met by greater utilization of farm- and orchard-produced seeds, nuts, fruits and beans in America—tomato, grape, walnut, pecan, apricot, prune, grapefruit, orange, peach, melon, cotton, peanut, corn, soybean, olive, perilla, castor, sunflower, sesame and avocado.

A good substitute for the bland fatty acids derived from seeds and nuts, is tall oil, a by-product of the paper-pulp industry. (*D. J. Bachrach, Chemurgic Digest 5(13): 232. 1946*).

Effects of Manuring on Growth and Alkaloid Content of Medicinal Plants

Nitrogenous fertilisers, in particular, have been found to stimulate growth and increase the alkaloid content of Atropa Belladonna.

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Introduction

THE effects of manuring with organic manures and inorganic fertilisers on alkaloid-forming plants have been studied in considerable detail during this century because of the important medicinal products which are obtained from many of these plants. Most of the work came from the continent of Europe, and some from the U.S.A., but of recent years the urgency of war has stimulated work in Great Britain also, and it may be of interest to workers in the U.S.A. to have the European work, including recent work in Great Britain, summarised as well as that of their own country. In the present paper it is proposed to deal especially with the alkaloid-producing drug plants, with only brief reference to relevant work on other alkaloid-producing plants such as tobacco.

Most of these plants, including *Atropa Belladonna* L., *Hyoscyamus niger* L. and *Datura Stramonium* L., will grow in North Temperate regions, and are cultivated in both Europe and North America; they also grow as native or naturalised wild plants in parts of both continents. Cinchona is, of course, tropical in its habitat, and is cultivated in the more tropical parts of the U.S.A. and of the British Commonwealth and U.S.S.R.; it is still collected in its native habitats in the Andes.

As early as 1908 Carr and Reynolds were publishing work on the cultivation of *Atropa Belladonna* in the U.S.A., and about the same time several workers in Germany, Austria and Hungary were investigating the effect of farmyard manure and "artificial fertilisers" on the alkaloid drug plants. At an early stage it became evident that at least three separate effects had to be taken into account: the effect on growth of the plants and so on the total yield of the plant material; the effect on the alkaloid content of the plant expressed in milligrams; and the effect on the "assay", or alkaloid content, expressed as a percentage of the dry weight of the plant. These three aspects will now be considered in more detail.

Effect of Manuring on Growth and Yield

Most of the earlier work in Europe was concerned with *Datura Stramonium* and *Hyoscyamus niger*, presumably because *Atropa Belladonna* grows so freely as a wild plant that its cultivation was considered to be of minor importance. There is very general agreement that the effect of farmyard manure and other nitrogenous fertilisers of various kinds is to increase the growth of individual plants in both species and so to increase the total yield of plant material. In 1911 yields from *Datura Stramonium* were reported as increasing from 23 kg.

per 100 square metres on unmanured land to 33 kg. per 100 square metres on land which had been dunged with farmyard manure (15). The investigators also reported that such treatment increased the ash content of the material from 16% to 18% of the dry weight. These results were confirmed and extended in 1923–1924 by others (9) who tried the effect of cow manure and also of various nutrient salts, and found that rich nitrogen manuring of all types tends to raise the yield. In 1930 Boshart (1) again reported increased yields as a result of dunging, but emphasised the facts

TABLE I

EFFECT OF MANURIAL TREATMENTS ON DRY WEIGHT OF *Datura Stramonium* AND *Hyoscyamus niger*

Treatment	D.W. = Total harvest in gm.		
	D. Stramonium	*H. niger*, annual	*H. niger*, biennial
No addition	290	430	560
P	310	450	510
K	320	420	470
N	270	570	730
NK	280	600	830
NP	370	590	700
PK	260	500	690
NPK	350	630	700

that balanced manuring is necessary for healthy growth, and that unbalanced manuring, especially with potassium but also with phosphorus and magnesium, may lead to a decrease of yield. Others (5) in 1932 confirmed the importance of balanced manuring for healthy growth; working with *Datura Stramonium* and *Hyoscyamus niger*, both annual and biennial forms, they used a soil poor in humus, dunged the previous year, containing 10.47% $CaCO_3$, 0.2% N, 0.14% P_2O_5, 0.57% K_2O, and added nitrogen, phosphorus and potassium fertilisers; nitrogen was applied as $NaNO_3$ equivalent to two gm. N per square metre, phosphorus as superphosphate equivalent to six gm. P_2O_5 per square metre, and potassium as various potash salts equivalent to four gm. K_2O per square metre. The dry weight as total harvest in grams is given in Table I.

From these figures it is evident that, although nitrogen manuring usually increases yield, especially with *Hyoscyamus*, unbalanced manuring with other nutrients tends to decrease yield, or only to increase it by a comparatively small amount. The balance between the three nutrients is a much more important factor, especially the balance between nitrogen and phosphorus with *Datura Stramonium*, and between nitrogen and potassium with both forms of *Hyoscyamus niger*.

In 1936 a review of experimental work (4), especially in Austria and France, on a number of drug plants, including *Datura*, *Atropa*, *Hyoscyamus*, *Aconitum* and *Lobelia*, stated that it was generally agreed that in all these genera, manuring, especially rich nitrogen manuring, increases growth and so yield of plant material. Organic manures, such as horse manure and fertilisers of the type of nitro-lime, are especially effective with *Atropa Belladonna*. Work reported in a later review (3) showed that ammonium sulphate or calcium nitrate is just as effective in stimulating growth of these plants as stable manure or compost. Dafert also reported a series of experiments by Salgues on a variety of plants, growing on different types of soil. The plants included *Hyoscyamus niger*, *Colchicum autumnale* and *Aconitum Napellus*, and Salgues was able to show that the type of soil and also the age of the plant had a very definite influence on the effect of a particular manure. For example, a series of experiments was carried out with *Hyoscyamus niger* (biennial), using nitrogen, potassium and phosphorus fertilisers with an unmanured plot as control; four types of soil

were used, containing (*a*) silica and lime, (*b*) silica and clay, (*c*) clay and lime, and (*d*) silica only. In the first year the highest yield of leaves per plant on silica-lime soil came from the unmanured plot; on silica-clay soil from the nitrogen-manured plot; on clay-lime soil from the nitrogen-manured plot; and on siliceous soil from the nitrogen-manured plot; in the second year the potash-manured plot on silica-lime gave the highest yield and also on siliceous-clay soil. On clay-lime soil nitrogen manuring was again highest, but potash was best on siliceous soil. In the present author's opinion it is doubtful that a sufficiently large number of replications was used to give really reliable results, but this series of experiments is useful in indicating the great importance of the nature of the basic soil in practical cultivation. In experiments with *Colchicum*, phosphorus gave better yields than nitrogen, especially on lime-containing soils.

Dafert reported that in his own experiments manuring generally led to increased yield of green plant material and that the most beneficial manurial substance depended on the particular plant in question.

In 1939 Ozterov (17) reported that application of potassium nitrate to plants of *Cinchona succirubra* raised from vegetative cuttings increased the yield, whereas ammonium salts may lower yield, owing to damage to the plant. Yield was also increased by phosphorus, but most of all when a correct balance was obtained between nitrates and phosphorus salts. He also reported considerable variation in the effects shown on soils of different types, thus confirming the work of Salgues with other alkaloid-forming plants.

In 1942 W. O. James, working at Oxford, England, reported the results of a series of field experiments and pot cultures with *Atropa Belladonna*. In the field plots on a clay-lime soil, half were top dressed with sulphate of ammonia at the rate of 1½ cwt. per acre, applied during the second half of May. The plants were second-year plants and were sampled and cut down at the end of the first week in July. They sprouted again rapidly, especially on the dressed plots, and were cut again during the second week in September. No significant difference was found between manured and unmanured plots in the first sampling, but in the second sampling, the dry weight of leaf per plant was increased by 68%, on the average, on the plots dressed with sulphate of ammonia, and the number of new sprouts per plant was increased by 30%. In the pot experiment a good alluvial soil mixed with an equal volume of washed sand was used as a base, and seedling plants were used. When they were established, half the pots were dressed with ammonium sulphate (13 gm. per pot), and the dressing was repeated in June and again in August. On hot days during July and August the plants in the dressed pots tended to wilt, while those in undressed pots did not, but by the end of August the growth of the plants which had a dressing of sulphate of ammonia was much greater than that of the plants which had no dressing. The plants were harvested at this time and the dry weight per plant was increased from eight gm. with no addition of sulphate of ammonia to 20.3 gm. with sulphate of ammonia. In 1943 a field experiment was carried out with top dressings of sulphate of ammonia at the rate of 0, 1, 2, 4 cwt. per acre and the results are summarised in Table II.

It is evident from these figures that ammonium sulphate causes an increase of yield with moderate dressings but a fall at higher concentrations. A pot experiment was carried out at the same time using seedling (first year) belladonna plants and four different nitrogenous fertilisers—sulphate of ammonia,

TABLE II

EFFECT OF SULPHATE OF AMMONIA ON DRY WEIGHT OF *Atropa Belladonna.* DATA OF W. O. JAMES *et al.*

Cwt. $(NH_4)_2SO_4$ per acre	0	1	2	4
Gm. d.w. per plant	26.3	30.3	24.8	24.7

nitrate of soda, nitro-chalk, dried blood —and a control set with no additional nitrogen. The top dressings were calculated to provide the same weight of nitrogen. Table III summarises the dry weights obtained.

It is evident that all the nitrogenous fertilisers caused large increases of growth of stem and leaves, which is in agreement with the results of earlier workers; but fertilisers containing nitrogen in the form of ammonia, such as ammonium sulphate and nitro-chalk, cause a decrease in dry weight of roots, whereas other nitrogenous fertilisers cause a marked increase.

Experiments reported in 1944 and 1945 with the mineral fertilisers potassium, calcium and phosphorus, supplied in addition to nitrogen, indicate that these elements have little effect on growth compared with nitrogen, though lack of phosphate seems to involve poorer leaf development, and lack of calcium a

TABLE III

EFFECT OF VARIOUS NITROGENOUS FERTILISERS ON DRY WEIGHT OF *Atropa Belladonna.* DATA OF W. O. JAMES, REARRANGED

Treatment	Gm. d.w. of leaf per plant	Gm. d.w. of stem per plant	Gm. d.w. of root per plant
No nitrogen	9.8	4.9	23.1
Nitro-chalk	23.2	11.9	21.7
Ammonium sulphate	23.6	10.4	22.3
Sodium nitrate	20.9	11.9	35.1
Dried blood	23.2	10.7	25.0

poorer root development. James confirms the emphasis laid by earlier workers on the need to secure a reasonable balance when mineral fertilisers are used, as well as rich nitrogen supply.

To summarise, it may be said that there is very general agreement that rich supplies of nitrogen increase growth of stem and leaf, and so tend to increase the yield of plant material, but that high concentrations of nitrogen in the form of ammonia may cause decrease of yield, and especially a decrease in the dry weight of roots produced. Other mineral elements have much less effect on growth than nitrogen, but phosphorus tends to increase growth slightly in most of these plants, and there is some indication that calcium may have a similar effect on the root systems, especially of *Atropa Belladonna.* In all the more recent work it is emphasised that a balanced fertiliser is essential for healthy growth, and that overmanuring with any one substance (except perhaps nitrogen in the form of nitrate) may be harmful. The effect of all mineral fertilisers is greatly influenced by the composition of the soil in which the plants are growing, and possibly also by the age of the plant. Others (14, 21, 22) have also shown recently that the pH value of the soil has an important effect on the growth of *Atropa Belladonna* and other alkaloid-forming plants, although another worker (16) in 1928 found little effect of pH with tobacco plants.

Effect of Manuring on Alkaloid Content

Results of work investigating the effect of various manures on the alkaloid content of these plants are much less consistent than those dealing with growth and yield. The alkaloid content may be expressed as a percentage of the dry weight of the plant material, as in the official methods of assay, or it may be given as milligrams of alkaloid per plant

or per square decimetre of leaf surface, and various workers have expressed their results in different ways.

Before considering the effect of manuring on alkaloid formation it is essential to point out that changes in the dry weight of the plant will affect the "assay", or alkaloid expressed as a percentage of the dry weight, even if there is no change in the rate of alkaloid formation or in the amount of alkaloid accumulated in the plant. Thus an increase in dry weight, with no change in alkaloid formation, will cause a decrease in "assay", while a decrease in dry weight will cause a corresponding increase in "assay"; it follows that assay values are not a satisfactory basis for the study of changes in the amount of alkaloid stored by the plant, unless corresponding changes in dry weight are also known. This is rarely possible in an experimental study extending over a period of time, and a safer basis for comparison is the total alkaloid content, expressed as milligrams per plant. This fact has often been overlooked in published papers, and erroneous conclusions have often been drawn from "assay" values as a result.

In a paper already referred to (15), it was reported that dunging with farmyard manure had no significant effect on the assay of *Datura Stramonium*, but some years later the view was expressed (9) that nitrogen manuring favours alkaloid production in this species. After further investigation the latter author (1) came to the conclusion that unbalanced manuring leads to a decrease in alkaloid formation, especially with potassium salts. In 1932, in the series of experiments described in the preceding paragraph (5), analyses of experimental plants of *Datura* and *Hyoscyamus* confirmed the need for balanced manurial treatment. Nitrogen manuring appears to favour alkaloid formation, especially in the biennial form of *Hyoscyamus niger*, as both assay and total alkaloid are increased; the total alkaloid increases from 83 mg. to 117 mg. per square metre, and the assay from 0.0135% to 0.0152%; these figures are the means of four experiments quoted in each case. With the annual form of *Hyoscyamus* the alkaloids increased from 66 mg. to 83 mg. per square metre, but the assay decreased from 0.0146% to 0.0139%. With *Datura Stramonium* there was no significant difference in either assay or total alkaloid as a result of nitrogen manuring. Unbalanced manuring with potassium or phosphorus gave very erratic results, with a slight indication of lowering of both assay and alkaloid content, especially with *Datura* treated with potassium. In their summarising report of 1936, the authors say that there is general agreement that assay is little affected by nitrogen manuring in both *Datura Stramonium* and species of *Aconitum*, but that in *Lobelia* there is a small but definite reduction of assay as a result of nitrogen manuring. As pointed out earlier in this section, this might be a result of an increase in dry weight, with no change in alkaloid formation. *Atropa Belladonna* and *Hyoscyamus niger* seem to behave alike, and results reported by different workers are contradictory. Little or no effect is found by some investigators, while others report increase of assay with heavy nitrogen manuring. Boshart and Klan agree that unbalanced potassium tends to reduce alkaloid content, and Klan adds that phosphorus, magnesium and calcium also decrease assay unless in balanced mixtures. In a later report Dafert (3) devoted considerable attention to a long series of experimental results published by Salgues, which indicates a possible explanation of the contradictory results published by earlier workers. Salgues used various types of soils as culture media and then added different manures, and was able to show that the effect of the manurial treatment

was very greatly influenced by the type of soil. His results indicate that with biennial *Hyoscyamus niger* nitrogen manuring leads to an increased assay only on heavy clay-containing soils, but that on light soils, without clay, and with or without lime, there is a decrease in assay as a result of nitrogen manuring. There is a consistent reduction of assay with unbalanced potassium manuring, and either reduction or very little effect with unbalanced phosphorus. Salgues also noted an age effect; the differences were greatest in the first year of growth, and much less in the second year.

The effect of the manurial treatments also varied with the different species examined, and also in different parts of the plant. For example, phosphorus manuring gave better results than nitrogen manuring with *Colchicum,* and this effect was especially noticeable in soils containing lime. With *Aconitum* the alkaloid content of the tuber was increased as a result of added potassium, though only if there was sufficient phosphoric acid present also; the alkaloid content of the leaves was most increased by application of nitrogen.

Preliminary experiments by Chanduri were also quoted in this review, indicating an increase in alkaloid content of *Atropa Belladonna* as a result of treatment with the ammonium salt of asparaginic acid, but this result seems to be of more theoretical than practical value at present.

Dafert himself considers that normal balanced manuring does not usually increase the alkaloid content of these plants, but that such an increase is usually due to unbalanced manuring with the particular nutrient that best suits the plant concerned.

It is of interest at this point to note that several workers (*e.g.*, 6, 16) have reported considerable increases in the nicotine content of tobacco leaves as a result of nitrogen manuring, especially with ammonium salts. Dawson states that heavy doses of ammonium salts may cause ammonia damage to the plants, but that in spite of this the percentage of nicotine is high.

The reports of the Oxford Medicinal Plants Scheme, whose research work is directed by W. O. James, show consistent increases in both assay and total alkaloid in *Atropa Belladonna* growing on clay-lime soils as a result of nitrogen manuring. In 1942 a mean increase in assay from 0.44% to 0.48% was reported for plants grown on field plots, and from 0.21% to 0.30% for plants grown in pot cultures. The total alkaloid increased

TABLE IV

EFFECTS OF DIFFERENT RATES OF APPLICATION OF AMMONIUM SULPHATE ON THE ASSAY AND TOTAL ALKALOID CONTENT OF PLANTS OF *Atropa Belladonna*. DATA OF JAMES *et al.*

Cwt. $(NH_4)_2SO_4$ per acre	0	1	2	4
l-hyoscyamine % D.W. = assay	0.29	0.30	0.35	0.47
Total alkaloid expressed as mg. *l*-hyoscyamine per plant	76.3	90.9	86.8	118.1

in the pot culture plants from 17 mg. per plant to 60 mg. per plant, this figure being the mean of ten experiments. In 1943 the experiments were designed to test the effect of different strengths of top dressings of ammonium sulphate, and showed that assay and total alkaloid values rise, even with applications of ammonium sulphate which decrease the yield. This is clearly shown if the data given in Table IV are compared with those in Table II.

The effect of nitrogen manuring on alkaloid content in *Atropa Belladonna* being so striking, a series of experiments was carried out to determine whether different types of nitrogen fertilisers showed different effects. Effects on growth have been discussed earlier in the present paper, and the effects on assay

and total alkaloid content of different parts of the plant are summarised in Table V.

It is evident from these figures that all types of nitrogen fertiliser cause increase in both assay and total alkaloid per plant, although they do not always have a favourable effect on the dry weight (see Table III). The fertilisers which contain nitrogen in the form of ammonia (nitro-chalk and ammonium sulphate) gave smaller increases than those which do not contain ammonia (sodium nitrate and dried blood). In spite of the unfavourable effect on growth noted earlier of high concentrations of ammonia-containing fertilisers, both assay and total alkaloid are increased at all concentrations tested at any time. Ammonia damage to the plant can often be noticed in the form of scorching of the leaves, easily induced wilting, *etc.*, but in spite of this, alkaloid formation increases.

Experiments with plants on field plots instead of pot cultures showed less effect, probably because the untreated plots gave fairly high values, owing to the fertility of the soil. The total quantity of alkaloid per plant was always increased, and more so with nitrate than with fertilisers of the ammonia type, but the assay was more variable, and even showed a slight decrease in some cases.

Experiments with the nutrient elements calcium, phosphorus and potassium, in addition to nitrogen, indicate that the effect of these substances on alkaloid content is much less than the effect of nitrogen. The figures quoted in the reports for 1944 and 1945 indicate that assay is lowered by addition of unbalanced potassium in *Atropa Belladonna* and raised by addition of phosphorus. Calcium seems to have little or no effect on formation of alkaloid in this plant, although with clay-containing soils especially it has an effect on the general growth of the plant.

It is interesting to note that Ozerov (17) reports that with *Cinchona* plants raised from vegetative cuttings nitrogen acts as "a stimulator of alkaloid storing" and increases the alkaloid content of the plant when it is applied in the form of nitrate or of ammonia, in spite of visible damage to the plants, especially to young plants, by ammonia. Much earlier Broughton (1873) reported increase of alkaloid content in *Cinchona succirubra* and *C. officinalis* when mature trees were manured with either guano or farmyard manure.

Ozerov also reports that phosphorus has little effect on alkaloid percentage or may even reduce it.

TABLE V

THE EFFECTS OF VARIOUS NITROGEN TREATMENTS ON DIFFERENT PARTS OF THE PLANT OF *Atropa Belladonna*. POT CULTURES. DATA FROM W. O. JAMES *et al.* 1943

Treatment	Assay %			Mg. alkaloid per plant			
	Leaf	Stem	Root	Leaf	Stem	Root	Whole plant
No nitrogen	0.21	0.21	0.31	20.8	10.3	71.6	102.7
Nitro-chalk	0.29	0.24	0.45	67.7	28.3	94.6	190.6
$(NH_4)_2SO_4$	0.30	0.27	0.42	70.8	28.1	83.8	192.7
$NaNO_3$	0.40	0.28	0.39	83.6	33.3	136.9	253.8
Dried blood	0.42	0.24	0.53	97.5	25.6	132.4	255.5

Summary

It may be stated with confidence that nitrogen manuring is very beneficial to the alkaloid-forming plants, especially on soils containing a proportion of clay and lime; it is hardly possible for grow-

ers to over-manure on such soils with any nitrogenous fertiliser; growth of the plant is stimulated to a remarkable degree by such treatment, and in the case of *Atropa Belladonna* the rate of sprouting after cutting is also increased. Thus the crop obtained in any one season is increased very considerably as the result of treatment with nitrogen. Ammonium sulphate may produce damage and even a decrease of total yield if applied in high concentrations, though it increases alkaloid content in spite of this damage. Dressings at the rate of $1\frac{1}{2}$ cwt. (about 160–170 lbs.) per acre are very beneficial to the crop. Other mineral fertilisers have very much less effect, but the usual balance between nitrogen, phosphorus, potassium and calcium produces the best results. The effect of calcium on *Atropa Belladonna* seems to be on the general growth of the plant and not at all on the alkaloid content.

Too heavy a dressing of the elements other than nitrogen, on the other hand, may have a deleterious effect, varying with the particular element and the particular plant in question. It seems quite clear that the best results are produced when there is a reasonable balance between the main nutrient elements, combined with a rich nitrogen supply.

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Utilization Abstracts

Charcoal. At the pilot plant of the Oregon Forest Products Laboratory experiments are being conducted on the carbonization of wood-waste in the form of headsaw sawdust and on the production of tarbound charcoal briquettes. The products are charcoal, tar, pyroligneous acid and gas. "All previous attempts in the establishment of a wood carbonization plant in the Pacific Northwest have been confronted by marketing problems".

Charcoal is needed for the industrial development of the region, especially in electrochemical and electro-metallurgical factories; in making carbon disulphide for viscose rayon manufacture and for seed fumigants, weed eradicators and rodent exterminators; in iron foundries, alloy steel foundries and carburizing ovens; also in poultry feeds and as a soil lightener. (*H. G. Rieck, Jr., E. G. Locke and E. Tower in The Timberman, reprinted in Chemurgic Digest 5(16): 273. 1946*).

Peanut Oil. Bulletin 247 of the Georgia Experiment Station, issued in 1946, discusses the stability of peanut oil and gives a comparison of peanut oil with other cooking oils.

Hawaiian Food Plants. "Foods used by Filipinos in Hawaii" is the title of Bulletin 98 of the University of Hawaii Agricultural Experiment Station, published in 1946. (*C. D. Miller, L. Louis and K. Yanazawa*).

Forest Products of Ecuador. During the recent World War the forests of Ecuador were the source of most of the world's supply of balsa, as well as of significant amounts of rubber, cinchona and kapok. With the exception of balsa [*Ochroma Lagopus*], little wood is exported. Though balsa grows also in Colombia, Brazil, Venezuela and parts of Central America, Ecuador has long supplied 90% of the commercial product; in 1942 and 1943 it was the principal forest export of the country, even surpassing Panama hats. Before 1941 balsa was used for making toys, movie sets, life preservers and insulation; since 1941 its uses have multiplied, and it became a strategic war material in the construction of Mosquito bombers, life preservers and rafts. Export of the material from Ecuador increased from an annual average of about 4½ million pounds in the 1936–1940 period to over 30 million pounds in 1943, since which time the quantity shipped abroad has dropped. About 90% of the war-time shipments came to the United States. Balsa trees grow 50 to 100 feet tall, but are ready for cutting when only two years old; the most economical cutting age, however, is between six and nine years. Nearly all the commercial supply is obtained from wild trees, but there is also some plantation balsa. The logs are floated down the rivers of Ecuador as rafts to the saw mills near the coast, where they are cut into lumber, and the latter either kiln-dried or sun-dried prior to shipment abroad.

Wild trees of *Castilla elastica* have long supplied small quantities of rubber for export, reaching a peak of 6½ million pounds in 1942, but the material has been classed as "scrap" in world markets. *Hevea brasiliensis,* the great rubber species of Brazil, is a potential source of commercial rubber in the country, and in 1941, through cooperation of the Ecuadorian and United States Governments, two hevea nurseries were established in which "thousands of trees have been produced from both imported and local seeds, and budded stumps and budwood of hevea trees have been imported and tested for adaptation to Ecuadorian conditions".

Cinchona bark is obtained mainly from two species of tree, *Cinchona officinalis* with gray bark and *C. succirubra* with red bark. The former is sent almost exclusively into Peru, while the latter is usually shipped abroad from Guayaquil. The bark of *C. officinalis* and of *C. pitayensis,* the latter found mainly in the eastern cordillera, is at present inaccessible because of inadequate transportation facilities. Most Ecuadorian cinchona bark comes from wild trees, but a few farmers have planted small acreages with the trees. Felling the trees usually begins in August; the bark is removed with machetes and dried over fires or in kilns. Under war-time demands exports of the bark rose from 207,000 pounds in 1942 to 7,000,000 pounds in 1944, all of it coming to the United States. Before the war Germany and Japan were the principal markets.

Tagua nuts, the seeds of a palm [*Phytelephas macrocarpa*], constitute one of the more important minor products of Ecuador. The nuts resemble ivory in hardness and durability, and have been important primarily in the manufacture of buttons, secondarily in that of novelty items, *e.g.*, chess men, dice, poker chips, umbrella handles and religious ornaments. Plastics are now competing strongly with the nuts in the making of these items. Wild trees are the sources of the nuts. The trees grow in jungle areas from Panama to Peru, but Ecuador is the center of production. As a result of demands for strategic materials during the recent war, exports of tagua nuts from Ecuador declined from 56¾ million pounds per year for 1935–1939 to 29½ million pounds in 1942.

Before the recent war Ecuador was second to the Netherlands East Indies, particularly Java, in the production of kapok fiber, extensively used as a filler in life preservers, mattresses, pillows and other items for which buoyancy, lightness and resistance to moisture absorption are important. Ninety percent of the supply formerly came from the Indies. The white fleecy fiber is the floss produced on the seeds of the ceiba tree [*Ceiba pentandra*] and is collected from trees along the coast. Secondary products of economic importance furnished by the tree include a medicinal gum from the trunk, a

rubber-like substance from the bark, edible oil from the seeds, and lumber. Exports have varied from 20,000 pounds in 1932 to over 1¼ million pounds in 1938.

The bark of mangrove trees (*Rhizophora* sp.), growing up to 150 feet tall in coastal sections of the country, is the principal source of tanning materials for use in the country itself. On the highlands a secondary source is a bark obtained on the paramos and known as "casca". More than 6½ million pounds of bark are extracted annually, and nearly 8 million more pounds used in local tanneries.

Panama hats, made from the leaves of the toquilla plant (*Carludovica palmata*), have long been a staple export item of Ecuador, reaching an estimated 4,400,000 hats in 1944, second only to rice in export value. Small amounts of the straw itself are also exported. "Toquilla straw comes from a small fan-shaped 'tree' without a trunk, which usually grows wild on the heavy fertile soils of the lowlands. The leaves grow to a length of from 5 to 7 feet and must be cut from the plant before they open. They are stripped of their outer filaments and the remaining fibers are dipped into boiling water, dried in the shade, and bleached in the sun before they are woven into hats. An average of approximately one-half pound of fiber is used for one hat. The making of the hats is a cottage industry, the quantity of fiber gathered and processed depending on the price for hats". (*Kathryn H. Wylie, Foreign Agriculture 10(5): 75. 1946*).

Origin of Cucurbits. The problem of the origin and subsequent domestication of the three annual cultivated species of *Cucurbita* (*C. Pepo* L., *C. moschata* Poir and *C. maxima* Duch.) has been reexamined, and a domesticated form of *C. Pepo* from southwestern United States described for the first time as distinct from others. The investigation endeavored "(*a*) to point out the essential differences between the three domesticated species; (*b*) to furnish evidence that there were at least two independent domestications of *Cucurbita Pepo;* (*c*) to show that these separate domestications produced distinct varietal types; (*d*) to correlate these findings with previous work so as to construct a theoretical picture of the relationships of the entities which exist within the domesticated cucurbits". (*T. W. Whitaker and G. F. Carter, Am. Jour. Bot. 33(1): 10. 1946*).

Brazil-nuts. Brazil-nuts [*Bertholletia excelsa*], known in Boston as "castanas" and in some parts of the southern United States as "nigger toes", are again among Brazilian imports into the United States after nearly four years of war-time absence. The former name, of Brazilian origin, was introduced by Yankee skippers of sailing ship days.

Brazil-nut trees grow almost exclusively in the upper reaches of the Amazon, and the nuts are floated down the river in barges to Manaos and then on to Belem, where they are graded and shipped to Europe and the United States. The trees grow 150 feet tall, preferably on high land far from the periodic overflow of the Amazon and its tributaries.

The nuts are borne within hard, spherical, thick-walled husks weighing two to four pounds, each shell enclosing numerous nuts. When the fruits ripen and fall they constitute a serious menace to the natives—"castanheiros"—who gather them.

Displacement of Brazil-nuts by minerals and other strategic materials in the exports from Brazil during the war meant a loss of about $15,000,000 so far as the traffic in those nuts was concerned. (*J. P. Lee, Brazil 20(6): 2. 1946*).

Japanese Mint. Japanese mint, *Mentha arvensis* var. *piperascens*, is the only practical commercial source of menthol, so extensively used in prescriptions, cold remedies, cough drops, dentifrices, mouth washes, cosmetics and tobacco. The plant is known also as "Japanese peppermint" and "hakkamaru", and is believed by some authorities to be a hybrid between *M. arvensis* and *M. aquatica*. It grows wild in nearly every bit of wet ground in Japan from Karafuto to Taiwan, and the two main producing regions within recent years have been the Province of Kitami on the Island of Hokkaido in northern Japan, where 70% to 80% of the Japanese mint oil is produced, and the District of Sam-bi in southwestern Japan, where 20% to 25% is produced. The leaves, stems and calyces of this perennial herb bear both glandular and non-glandular hairs, and the

menthol is dissolved in the volatile oil of the glandular heads on the hairs bearing them.

Prior to World War II production of mint oil and of menthol was one of Japan's principal chemical industries, and that country furnished most of the menthol used in the United States which consumes more than half of the world's annual production of about one million pounds.

The flavor of the oil of Japanese mint is inferior to that obtained from peppermint (*M. piperita*), but it has a higher menthol content—75% to 80% rather than 50% to 55%. This lower content of menthol in the oil of peppermint, costly and difficult extraction of it, and great demand with high prices for the oil itself, make it impractical to obtain natural menthol commercially from peppermint.

Rhizomes, cuttings from aerial runners, and stem cuttings are used for propagation purposes; seeds do not breed true. About 16000 cuttings are planted per acre. (*H. W. Youngken, Herbarist No. 12. 1946*).

Fats and Proteins from Cucurbits. In all parts of the world where squash is grown, except in the United States, the oil-containing seeds are relished as food and eaten as nuts. In the Balkan countries the oil of cultivated cucurbits is highly prized as a cooking fat, and in China watermelons are grown exclusively for their seeds.

The seeds of cucurbits are rich in fats and protein, and the three wild perennial species in southwestern United States, ranging from Missouri to California and south into Mexico, may offer sources of these essentials to the natives of those regions and to a fat- and protein-hungry world. Those three species, existing particularly in the desert, are *Cucurbita foetidissima*, *C. palmata* and *C. digitata*. The seeds of the last-mentioned were used as food by the American Indian.

Under cultivation these plants should produce approximately 1,500 pounds of seed per acre, about one-third of which weight would be attributable to the oil content and another third to the protein content.

In the Sahara Desert of eastern Morocco the author found a plant of *Citrullus Colocynthis* which occupied about 36 square feet of ground and produced 63 fruits, 25 of which contained exactly two pounds of seed. At that rate an acre supporting 1,210 plants six feet apart would produce roughly 6,000 pounds of seed.

In the seeds of perennial cucurbits there thus is a possibly great source of oil, not only for dietary use but also for manufacture of soap in such needy parts of the world as Mexico, Puerto Rico and North Africa. Nothing has yet been done about the matter, not even experimentally. (*L. C. Curtis, Chemurgic Digest 5(13): 221. 1946*).